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Marine Biodiversity Impact Assessment and Management Plan for the Cold Water Plume from Floating Storage Re-Gasification Unit (FSRU) Proposed at Jaigarh Port, Ratnagiri, Maharashtra

SPONSORED BY
Jaigarh Port
Jaigarh, Maharashtra

JULY 2017

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Marine Biodiversity Impact Assessment and Management Plan for the Cold Water Plume from Floating Storage Re-Gasification Unit (FSRU) Proposed at Jaigarh Port, Ratnagiri, Maharashtra

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July 2017

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EXECUTIVE SUMMARY

1. INTRODUCTION

H-Energy Gateway Private Limited (HEGPL); is proposing to construct and operate an 8 million metric ton per annum Liquefied Natural Gas (LNG) Storage & Re-gasification Project at JSW Jaigarh Port on the west coast of India in Maharashtra (the "Project") by entering in a sub-concession agreement with JSW Jaigarh Port Ltd (JSWJPL). The Project is in close proximity to the GAIL's Dahej-Uran- Panvel-Dabhol pipeline (DUDPPL), as well as the Dabhol-Bangalore Pipeline (DBPL). Accordingly, the environmental clearance was obtained on the 19th December, 2013 (Vide F. no. 10-17-/2006-IA.III). The environmental clearance was for the water front Jetty, the approaches and the on shore facility including the storage tanks (2 nos and with another one in future), regasification, loading and dispatch facilities. However, with the demand for gas especially on the Konkan Coast of Maharashtra, is taking time to pick up and does not warrant establishment of a full scale land based facility. In addition, the establishment of the land based facility would take considerable time, on account of scale of construction involved consisting of 2 nos. 85 m diameter and 55 m high storage tanks among other things.

Accordingly, the project is envisaged to be implemented in a phased manner, to use the long construction period. Hence, phase I of the project will comprise Early Production Facilities (EPF) which will be in service for a period of approximately 5 years. By which time, the Permanent shore based Phase II facilities will be ready and FSRU will be discontinued.

While the Phase II operation consisting of the land based permanent facility has received the environmental clearance, the present report is part of the documentation for the proposed amendment in the Environment Clearance for the LNG Operation, in order to enable introduction of FSRU (Floating Storage & Regassification Unit) in the interim period while the detailing and construction of the shore based facility continues.

MoEF&CC vide letter dated 19th December, 2013 issued the environmental and CRZ clearance for expansion of of the port. The proposal for the introduction of a FSRU (6 MTPA) in early production phase was presented to the EAC (Infra-2) in their 10th Meeting held on 24th October, 2016. The EAC exempted the Project Proponent from preparation of the EIA-EMP report as well as the Public Hearing as there was no change in plant capacity. However, the EAC recommended a detailed marine, estuarine and creek impact assessment report and management plan through NIO or an institute of repute on marine ecology and biodiversity that should include intertidal biotopes, corals and coral communities, sea grasses and seaweeds, sub tidal habitats, fishes and other marine flora and fauna including, turtles, birds and marine animals inclusive of mammals.

M/s JSW Jaigarh Port Limited requested the CSIR-National Institute of Oceanography (CSIR-NIO) to assess the impact of cold and hot water discharge on the marine ecology off Jaigarh. The present Report is prepared to meet the requirements of the recommendation of the EAC referred in the preceding paragraph.

2. PROJECT DESCRIPTION

The decision to build a terminal at the chosen location follows a series of studies including an in-depth market analysis to assess the demand for LNG/ Natural Gas and a detailed Front End Engineering Design (FEED) study to ascertain the technical feasibility, sustainability, safety, risk and the social & environmental impact of construction & operations of the facility.

Based on market dynamics it has been decided to implement the project in a phased manner as follows -

- **<u>Phase–1</u>**: Early Production Facility (EPF) using leased LNG Floating Storage and Re-gasification Unit (FSRU) and Tie-in gas pipeline from Jaigarh to Dabhol and connection to the GAIL (India) Limited pipelines.
- **<u>Phase–2</u>**: Land based LNG terminal including LNG storage tanks and regasification facilities and gas pipeline from Jaigarh to Mangalore

Phase 1 of the Project will utilize Early Production Facilities (EPF) with the intent that the facilities to be installed will be minimized. The design will be based on a leased Floating Storage Regasification Unit (FSRU), which is essentially a LNG Carrier ship (LNGC) with High Pressure pumps and vaporization and gas send out facilities installed. The FSRU will be moored at the LNG Jetty, within Jaigarh Port. (The Jetty built in Phase 1 will also be utilized in Phase 2). The FSRU will receive LNG by Ship to Ship transfer from LNG Carriers (LNGC), which will moor side by side to the FSRU. LNG will be transferred from the LNGC to the FSRU via cryogenic flexible hoses. The FSRU will store, pressurize and re-gasify the LNG. The high pressure natural gas will be exported from the FSRU via articulated High Pressure Gas Unloading Arms mounted on one of the Breasting Dolphins near the jetty head and be transported via a gas pipeline from the jetty to the onshore terminal area (a distance of approximately 1 km), where gas meters and pig launching facilities will be located. From there the gas will flow via approx. 60 km gas pipeline to Dabhol.

The FSRU is essentially a conventional LNG Carrier with additional LNG vaporization & send-out facilities installed on the main deck. FSRU will use ambient seawater to vaporize the CNG and discharge seawater (15000 m^3/h), temperature of which will be about 7°C below the ambient seawater temperature. Another channel will be passed through the machine for cooling purpose and the water discharged (2000 m^3/h) will have temperature about 6°C above ambient temperature. The intake and outfall will integral part of the FSRU.

3. JAIGARH BELT

The coastal water of Jaigarh and the estuary does not receive any effluent from point sources and harbours luxuriant mangroves. The port is an active fish landing centre at this transect and has bauxite export from the port at Lavgaon and some industries are being set up around Jaigarh Port in recent years.

There are two monuments of historical and religions importance within the core area viz. Temple of Karteshwara and the Jaigarh Fort. The temple of Karteshwara or Shiva is located about 2 km south west of the proposed site on the slopes near the sea shore. Many devotees from all over Ratnagiri district visit this temple. The Jaigarh Fort is located about 2 km from the site. The Fort was built in 16th century by Shivaji as a naval base. Currently, the Fort is lying in state of neglect, with only a few tourists visiting it. At present the Fort is more often used to host various socio cultural activities of the nearby village.

JSW Jaigarh Port Ltd. is a subsidiary of Jindal South West group of companies and is governed by a board of Directors. Port is operational in Dhamankul BayJaigarh. The port is being developed as a deep sea water port, which will be catering to Panamax vessels of 60,000 to 70,000 DWT initially and Cape size vessels in the second phase. Jaigarh is connected by road with Ratnagiri town which is well connected to rest of the country by road and rail. The port will be functioning as a captive port for import of coal for sister concern, “JSW Energy” a thermal power station situated adjacent to the port itself.

The port is situated at about 60 km. North of Ratnagiri town. The Regional Port officer Ratnagiri is the supervisory authority from the Maharashtra Maritime Board. The port has been allotted sea front area along with required land to operate

It is also important to note that this area receives good amount of rainfall (3500 mm) during SW monsoon period and cyclones passing through or from nearby areas are quiet common. In other words the monsoon is quiet effective and vigorous in this stretch of Ratnagiri, Raigad district in north and Sindhudurg dist. in the south. In this backdrop the JSW Port assumes importance being strategically located and in private sector. All other minor / major ports are in Public sector. (Other private sector ports are having single captive jetties for their individual requirement).

4. DESCRIPTION OF MARINE ENVIRONMENT

The proposed project is located at JSW Jaigarh Port on the west coast of India in Maharashtra by entering in a sub-concession agreement with JSW Jaigarh Port Ltd (JSWJPL). The JSWJPL is situated on the mouth region of Shastri Estuary in Dhamankul Bay. The study area for field studies was therefore spread over the estuarine reach of Shastri Estuary and the coastal sea.

River Shastri is one of the few undammed, unpolluted and near pristine rivers in the Northern Western Ghats. The river emerges from Prachitgad, a historical fort in the newly-declared Sahyadri Forest Reserve at an elevation of 839 m above sea level and flows down to the west of the Sahyadri mountain ranges, meeting the Arabian Sea in a short journey of 90 km, forming a basin of 2173.55 km^2. The Konkan coast is characterised by pocket beaches flanked by rocky cliffs of Deccan basalt, estuaries and patches of mangroves. The coast is a narrow stretch with an average width about 30-50 km composed of strips of plain between the sea and the hilly terrain of the Western Ghats or Sahyadris which runs parallel to the sea coast.

5. ASSESSMENT OF WATER QUALITY

Water quality of present study indicated the air temperature varied in 23.0-30.0°C range and the water temperature was in the range of 26.5-29.5°C. Variations in temperature between the surface and the bottom were minor suggesting vertically well-mixed water mass. The average pH of the study area was 8.0-8.2 during present study and was well within the range of seawater. SS varied between 13 to 127 mg/l. The maximum SS was recorded in the creek, which may be due to disturbance by boat movements. Salinity was in the range of seawater salinity in the coastal water with tidal variations in the estuarine segment, indicating influx of freshwater during ebb. DO and BOD concentration did not show impact of any organic load in the region. The average concentration of PO_4^{3-}-P concentration was below 1 µmol/l and varied randomly depending upon time and season of collection. The average NO_3^--N concentration varied from 0.2 µmol/l to 17.6 µmol/l during March 2017 and the values were in the range generally observed in the nearshore uncontaminated coastal waters. The concentration of NO_2^--N was <0.6 µmol/l throughout the study region as expected in well-oxygenated waters. The NH_4^+-N concentration was high in the Upper Creek during the present study. Except during March 2016, the concentration NH_4^+-N in the estuarine region seems to have increased with time, indicating increased input from land based sources. The concentrations of PHc and phenols were low. Concentration of metals varied in accordance with lithological variation and values can be considered as baseline in the absence of significant anthropogenic source to the coastal area of Jaigarh. There is no build-up of PHc and phenols in the sediment.

6. FLORA AND FAUNA

The total viable bacterial populations in the water samples ranged widely from 20 x 10^2CFU/ml to as high as 14400 x 10^2CFU/ml. Total coliforms and faecal coliforms which are indicators of faecal pollution were below the detectable limits almost at all the sampling sites. In sediment the total viable bacterial populations in sediments ranged widely from 100 x 10^2CFU/ml to as high as 27000 x 10^2CFU/g.

Total coliforms and faecal coliforms were below the detectable limits almost at all sampling sites.

During March 2017, the distribution of chlorophyll *a* was patchy with values fluctuating from 0.3 to 5.1 mg/m^3 (av. 0.4 to 4.1 mg/m^3). The ratios of chlorophyll *a* phaeophytin showed random variations. However, the ratios at all the station was more than 1.0 which suggests favourable condition for phytoplankton growth.

There were no mangroves at and near the proposed project site. However, mangroves are present in the Shastri Estuary around 9.0 km away from the proposed FSRU site.

Zooplankton standing stock in terms of average biomass (23.4 ml/100 m^3) and average population (90.7 x10^3/100 m^3) varied widely and was indicative of an overall good secondary production potential of the region during the study period. The results indicated wide variations in the standing stock of zooplankton throughout the study area. The percentage composition of zooplankton consisted of high population of copepods (av. 86.4%), decapod larvae (av. 2.6%), Siphonophores (av. 3.1%) and lamellibranches (av. 2.2%). The composition was fairly diverse and the number of faunal groups varied between 15 and 21. Fish larvae (av <0.1%) were low in number in the zooplankton samples. Fish eggs (av. 0.2%) though at a low percentage, were encountered in most zooplankton collections. In general, the study area sustained low numerical abundance of fish larvae probably because the study area was not the breeding grounds of fishes.

The estuary recorded relatively high macrobenthic standing stock in terms of biomass and coastal water in terms of population due to dominance of polychaetes and amphipods estuary and coast respectively. Major faunal component in the study area were polychaetes followed by amphipods. Overall, 22 faunal groups were recorded in the area though on no occasion all groups were present at a given station. The faunal standing stock of benthic meiofauna in terms of population and biomass varied in a wide range. Major faunal component in the study area were nematodes followed by foraminiferans. Overall, 11 faunal groups were recorded in the area.

Experimental fishing was carried out during March 2017 off Jaigarh to assess the fishery potential in the mouth region of the Shastri estuary. The result indicated low fish catch rate with 2 kg/h.

The catches were represented by species .*Parastromateus niger*, *Parastromateus argenticus*, *Uroconger lepturus*, *Scomber microlepidotus*, *Cynoglossus clubius*, *Alectis cilioris*, *Nemipterus japonicas*, *Loligo, Sepia, Sciaena marleyi, Thryssa dussumeri*. There are many more species of commercially important species in this region.

Corals are absent off Jaigarh. In fact the area sustains high percentage of silt and clay – the conditions unfavorable for the reef-building corals to thrive. A total of 8 water species of birds were recorded during the study period.

Reptiles were not spotted during the present study in the area. Dolphins (*Delphinus delphis*) were recorded in this region during the study period.

7. BATHYMETRY AND PHYSICAL PROCESSES

The data of tide indicates that the spring tidal range was 3.0 m and neap range was 1.0 m. This shows that maximum tidal range at this location is 3 m. The average time lag between Apollo Bunder and Malwan was 1h 10 min in spring and 2 h in neap. Maximum current observed in the region was 0.55 m/s. The direction veered between 50º and 300º. This indicate that the currents changed from NE to NW direction in a tidal cycle which shows that the current were parallel to the coastline. The results of drogue trajectories indicated excursion length of 5.4 km in 4h 15 min in the flood condition while it was 3.5 km in 5h 30 min during ebb. Hence a particles released at station J9 would move in the Shastri estuary during flood and southward along the coast when released during ebb. The results show that the wave height ranged between 0.4 and 1.8 m.

8. NUMERICAL MODELLING OF HYDRODYNAMICS AND DISPERSION

In case of open loop option, the volume of seawater required for vaporize LNG is estimated at 15000 m^3/h and equivalent volume has to be released to the sea at temperature 7°C below that of the ambient seawater (cold water effluent). Seawater (2000 m^3/h) will also be used to cool the FSRU machinery and discharged to the sea with temperature 6°C above the ambient seawater temperature (warm water effluent). Seawater intake and effluent release are integral to the design and construction of FSRU and is directly withdrawn / released from the ship's hull. Since the locations of intake of seawater and release of effluents is integral to a FSRU, hypothetical locations – one each, for the intake of sea water and for discharge of the cold water effluent were selected for detailed modeling study. The outfall location for discharge of cold water effluent is at coordinates: 17°18'36.8" N; 73°11'42.0" E which is to the west of the warm water effluent discharge site at a distance of approximately 270 m.

Dedicated software Hydrodyn - FLOSOFT and Hydrodyn - POLSOFT for prediction of tides and currents and dispersion (pollutant transport) processes in the seas and estuaries developed at Environ Software (P) Ltd, Bangalore, were utilized for the studies.

The modeling of warm water results pertaining to variation of temperature at and around the discharge point for spring tide condition indicated that during spring tide at peak flood condition the dispersion is elongated towards the northwest with the central patch having a higher temperature but reached the ambient values within a distance of 50 m from the point of disposal. The variation of the temperature inside the patch is predicted to be in the range of 28.5^0 C to 29.0^0 C during different tide conditions. From the model result, it can be concluded that there will not be any recirculation and there will be no impact on water quality at the shore due to high dispersal of the effluent.

From the model output of cold water dispersion, it is evident that the dispersion is elongated towards northwest direction during spring tide with the central patch having lower temperature. The temperature has reached the ambient values within a distance of 50 m from the point of disposal. The maximum temperature drop is predicted as 0.32°C in spring tide at 50 m distance from the point of disposal. The variation of the temperature inside the patch will be in the range of 28.5^0 C to 29^0 C during the different tide conditions. It is also evident that there will not be any recirculation and there will be no impact on water qualities at the shore.

9. ANTICIPATED ENVIRONMENTAL IMPACTS & MITIGATION MEASURES

The proposed project is expected to pump around 17000 m^3/h sea water for regasification of LNG and cooling of machinery in the event of the open loop vaporisation system. The impact associated with the intake is due to Impingement, entrapment and entrainment of marine organisms. The volume of seawater intake and the cooled seawater discharge including the associated antifoulants in the effluent has the potential to impact juvenile fish. In the event that the closed loop vaporisation system is used, the water intake will be significantly reduced.

Since the seawater off Jaigarh is vertically well-mixed, withdrawal of seawater can be from any depth below the lowest low tide level. However, it is advisable to draw seawater (17000 m^3/h) about 3-5 m above the bed to prevent excessive silt getting sucked particularly during monsoon. In the present case the depth of intake will depend on the design of the FSRU. Appropriate screens should be provided in the intake to avoid large marine organisms entering the intake system. The efficiency of the intake system might decrease over a period of time due to the settlement of bio-foulers such as barnacles, at and inside the pipe opening, entry of sediment into the sump etc. Periodic removal of these materials will be required. The cleared materials should not be dumped to sea.

At all tidal conditions will be insignificant except for relative high temperature limited to a small area (less than 50 m radius). The variation of temperature inside the patch around the outfall point would be in the range 28.5^0 C-29.0^0 C. Also, due to high dispersion, there will be no impact on water qualities at the shore due to the release of warm water at the proposed outfall discharge location.

For cold water effluent release, the numerical modelling detailed the time-series variation in predicted temperatures at different locations around the outfall at all tidal conditions will be insignificant except for relatively low temperature limited to a small area around the release site (less than 50 m radius). The variation of temperature inside the patch around the outfall point would be in the range 28.5^0 C-29.0^0 C. Also, due to high dispersion, there will be no impact on water qualities at the shore due to the release of cold water at the proposed outfall discharge location. The cold water effluent (15000 m^3/h) can be discharged at a site about 2-4 m from the sea surface depending on the design of the FSRU.

If chlorination is done, then the free chlorine (total residual oxidant in estuarine / marine water) concentration in cooling / cold water discharges should ideally be maintained at 0.2 parts per million (ppm). This is in line with the "Environment, Health and Safety Guidelines for LNG Facilities" from International Finance Corporation's (under World Bank) for free chlorine in cooling/cooled water.

As per the Environment, Health and Safety guidelines of International Financial Corporation under World Bank for the offshore Oil & Gas Developments, Maximum difference of 3° C w.r.t. sea water temperature shall be maintained at 100 m distance from outfall location. Thermal impact model results indicate, the sea water temperature variation (drop) follows cyclic pattern. The maximum temperature drop is predicted as 0.32°C in spring tide at 50 m distance from above mentioned cool water outfall and for warm water discharge, the sea water temperature rise is predicted to attain ambient temperature at 50 m distance. From the modelling study it is found that the tidal hydrodynamics at proposed FSRU site are conducive for rapid dissipation of temperature (heat energy). As per prediction results, the cumulative temperature drop 0.32°C (Max.) at 50 m distance around proposed outfall locations will be well within the above mentioned guidelines limit of 3°C temperature difference and would not cause any adverse impact on surrounding marine environment.

Mangroves are sturdy intertidal plants which can tolerate minor changes in environmental attributes. Mangroves occur in the Shastri estuary and the nearest habitat is about 9 km from the proposed site of the FSRU. With the predicted insignificant changes in seawater temperature subsequent to the release of the FSRU effluents, these mangroves will not be negatively influenced.

10. ENVIRONMENT MANAGEMENT PLAN (EMP)

The guiding principal of environment management is to ensure that the perturbations due to the proposed coastal activities are within the assimilative capacity of the marine zone. This is best done by integrating into the project itself, a plan of actions for mitigating predicted adverse effects through an appropriately synthesized EMP. The EMP should deal with, control and disposal of waste from various point and nonpoint sources as well as inspection of structures and machinery to ensure reliable operations. A Waste Management Plan should be developed for waste collection, handling and disposal facilities for proposed project for environmentally compatible waste management. This plan has been drawn, in accordance with the latest MARPOL Regulations and also as MPCB / CPCB / MoEF & CC guidelines with respect to hazardous wastes and solid wastes.

11. POST-PROJECT ENVIRONMENTAL MONITORING

About 8 - 10 Stations sampled during the present study and parameters mentioned in the report should be considered for monitoring of subtidal ecology.

12. PROJECT BENEFITS

The LNG Terminal shall bring social benefits across the region by having consistent & reliable energy source; hence it is recommended that the project should be pursued while trying to optimize the costs and schedule. General benefits of major developments like LNG terminal are not only restricted to the financial benefits to proponent and government but also have several societal benefits. Benefits go beyond investment and returns due to the social gains from the project, i.e., improvement in quality of life by an improvement in physical & social infrastructure, employment generation etc. Project is expected to fuel industrial growth in the region it shall also open up avenues for indirect employment for local population. Since the LNG project is FSRU based, it will provide safe, sustainable and economic means of import, re-gasification and further distribution of natural gas in the state/country.

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1 INTRODUCTION

H-Energy Gateway Private Limited (HEGPL); is proposing to construct and operate an 8 million metric ton per annum Liquefied Natural Gas (LNG) Storage & Re-gasification Project at JSW Jaigarh Port on the west coast of India in Maharashtra (the "Project") by entering in a sub-concession agreement with JSW Jaigarh Port Ltd (JSWJPL). The Project is in close proximity to the GAIL's Dahej-Uran- Panvel-Dabhol pipeline (DUDPPL), as well as the Dabhol-Bangalore Pipeline (DBPL). The project intends business users to use the LNG terminal facilities for import, storage & regasification on a tolling basis. The decision to build a terminal at the chosen location is an outcome of in-depth analysis of the demand, techno-commercial feasibility, sustainability & environmental impact of construction & operations. Accordingly, the environmental clearance was obtained on the 19th December, 2013 (Vide F. no. 10-17-/2006-IA.III). The environmental clearance was for the water front Jetty, the approaches and the on shore facility including the storage tanks (2 nos and with another one in future), regasification, loading and dispatch facilities. However, with the demand for gas especially on the Konkan Coast of Maharashtra, is taking time to pick up and does not warrant establishment of a full scale land based facility. In addition, the establishment of the land based facility would take considerable time, on account of scale of construction involved consisting of 2 nos. 85 m diameter and 55 m high storage tanks among other things.

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1.1 PREAMBLE

Natural gas is a naturally occurring hydrocarbon gas mixture consisting primarily of methane, almost free from sulphur. In recent years, natural gas (NG) is the fastest growing primary energy source in the world. NG is widely available, and it is the cleanest burning petroleum based fuel. The low carbon dioxide emission and high calorific value of NG compared to other petroleum derivative fuels makes it favourable also in terms of the greenhouse effect and hence an environment friendly fuel.

The global market for NG is much smaller than for oil because gas transport is difficult and costly due to relatively low energy content in relation to volume. NG uses industrial, residential, electric generation, commercial and transportation sectors. NG is used across all sectors in varying amounts. Hence, the transport of natural gas in bulk quantity to different countries and also for long distances by converting the gas into liquid form i. e. liquid natural gas (LNG) up to 1/600th the volume of the natural gas is an economically beneficial option. The conversion of natural gas to its liquefied form can be achieved by cooling it to -162°C. This conversion is useful for maritime transport of LNG by carrier ships. Special infrastructure facilities termed as "LNG terminals" are required on the sea coasts for handling the import/export of LNG. These terminals can be developed either as independent projects or as part of already existing sea ports depending on the suitability/convenience.

1.2 NATURAL GAS SUPPLY CHAIN

Natural gas produced at oil & gas fields is liquefied at a liquefaction plant to produce LNG after removing the impurities and the various hydrocarbons and fluids from pure natural gas, producing what is known as 'pipeline quality' dry natural gas, also known as methane. LNG is then shipped through dedicated LNG carriers to the importing locations. After receiving the LNG at receiving terminals, it is regasified through vaporization thereby preparing it for use. This process occurs at regasification plants, where the temperature of LNG is increased, typically through seawater vaporizers, transforming it into gas. Regasified LNG [(RLNG)/natural gas)] is then sent out from the terminal through pipelines to the consumers. A schematic LNG supply chain is shown in following figure:

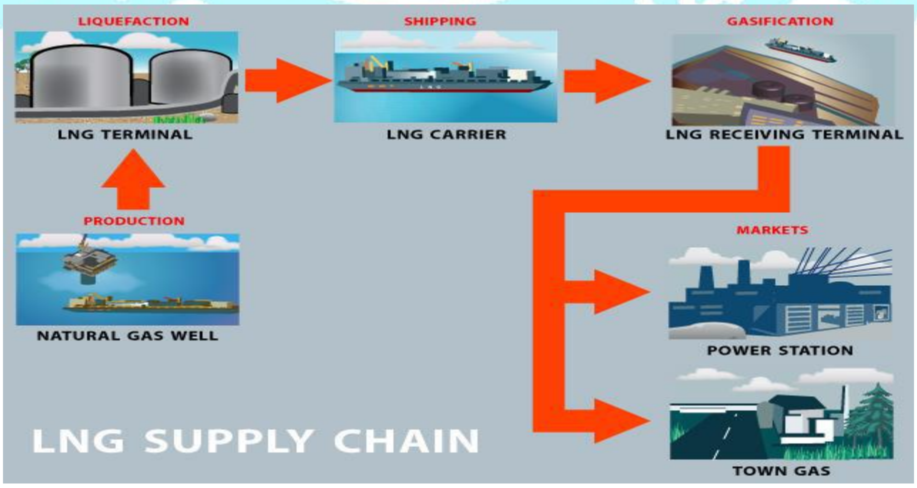


Figure 1.1: Supply chain of LNG

1.2.1 LIQUEFIED NATURAL GAS (LNG)

Liquefied natural gas (**LNG**) is natural gas (predominantly methane, CH_4, with some mixture of ethane C_2H_{6f}) that has been converted to liquid form for ease of storage or transport. It takes up about 1/600th the volume of natural gas in the gaseous state. It is odourless, colourless, non-toxic and non-corrosive. Therefore it is more economical to store and transport the liquefied form of the gas over long distances in contrast the traditional pipeline transmission of natural gas.

LNG is produced at atmospheric pressure by refrigeration process at -162°C after complete removal of impurities such as CO_2, water, sulfur etc., which may cause potential damage to tank/container walls (material) in long term storage. The end result of this process (LNG) is an odorless, colorless fuel consisting mostly methane (approx. 85% - 99%) with small amount of ethane, propane, butane and pentane.

1.2.2 BENEFITS OF REGASIFIED LNG (RLNG)

Re-gasified LNG is safe, cost effective and environment friendly as compared to other fuels. Re-gasified LNG is a clean burning fuel, which produces virtually no particulates and less NO_x and CO_2 compared to other fossil fuels. Since sulfur is almost entirely removed as part of the liquefaction process, combustion of re-gasified LNG emits negligible or no sulfur dioxide. LNG is stored at near atmospheric pressure, reducing the storage hazard compared to pressurized fuel like LPG. In case of minor spillage LNG evaporates and disperses quickly, leaving no residue behind and therefore requires no environmental cleanup. Therefore, it is envisaged to have negligible adverse impact on the environment & ecology. LNG vaporizes when warmed resulting in the formation of natural gas, which is lighter than air. Therefore natural gas has tendency to move vertically upwards, i.e. away from ground level, in contrast to the denser gases (heavier than air), viz. ammonia, LPG, chlorine etc. which have tendency to spread at ground level. LNG is non-corrosive and non-toxic.

1.3 PORTS & HARBOURS

Ports and harbours are the gateways of maritime trade and inland transport. Maritime transport is economical and the only means to transport larger volumes of cargo across oceans. Ports and harbours are, therefore, called upon to handle larger volumes of cargo throughputs of both raw material as well as products. Thus demand for handling bigger size ships and deploy state of the art cargo handling systems many a time require augmentation/expansion of facilities at existing ports and development of new ports and harbours. Similar to any major industrial and infrastructure development sector, the development and operation of ports and harbours (including terminals), the design as well as operation of ports/ terminals will require the integration of environmental protection and conservation measures for making them environmentally sustainable.

1.4 NEED OF PROPOSED PROJECT

Indian economy has been growing at the rate of around 7-8% and poised to grow at same rate in the years ahead. At this growth rate, the demand of energy is also expected to grow at 6-7% per annum. In India, contribution of natural gas, as a primary energy source is only around 10% as compared to the world average of 24%. India's natural gas market is characterized by supply deficit, primarily due to low domestic production and inadequate transmission and distribution infrastructure.

The domestic demand for natural gas far exceeds domestic supply, resulting in a deficit and increased reliance on LNG. The domestic gas production received a significant impetus with the commencement of production from the KG-D6 field, located in the east coast. However, recently due to technical difficulties, production from KG-D6 has declined significantly, which has resulted in a reduction in domestic supplies to the industries. Further, the decline in most of the country's ageing fields has further compounded the supply deficit. Over the next few years, the gas deficit in the country is expected to continue as the demand will be way ahead of supplies. The power and fertilizer segment accounted for the majority of the gas consumption in FY11 at 39% and 26% respectively.

The gas transmission network in India has increased from around 7,000 km in FY08 to around 12,000 km currently. GAIL (India) Limited owns majority of these pipelines, accounting for a 55% share of the total transmission capacity currently. Other major players are Reliance Gas Transportation Infrastructure Limited (RGTIL) and Gujarat State Petronet Limited (GSPL). The Government of India (GoI) and other stakeholders are encouraging investments to increase India's gas pipeline density. The Ministry of Petroleum and Natural Gas (MoPNG), in association with gas transmission companies, has envisaged a national gas grid in the country, connecting gas supply centers with major demand centers. Currently, more than 13,000 km of pipelines, with a transmission capacity of around 300 Million Matric Standard Cubic Metre per day (mmscmd), are in various stages of development in the country. The development of pipeline infrastructure will increase the demand of gas in the country.

India's dependence on imported LNG is increasing as a result of the country's lagging domestic production to address ballooning demand. There has been a significant increase in the contribution of LNG imports to the total supply of natural gas from 1% in FYO4 to 20% in FY11. India is currently the world's sixth largest LNG importer. Currently, there are two operational LNG terminals at Hazira and Dahej; with a total re-gasification capacity of 49 mmscmd. India's LNG re-gasification capacity is expected to increase significantly with the expansion of existing capacities and commissioning of new terminals. As a result, the share of LNG imports in total gas supply is likely to increase significantly in future.

CRISIL has undertaken an extensive market study on behalf of HEGPL to assess the natural gas market in India. As per the report, even after considering the announced plans of various players for developing newly discovered domestic fields and also the plans to expand/set up new LNG terminals; CRIS (research arm of CRISIL) projects the demand-supply gap to widen in the projection period from 11 mmscmd in FY11 to 133 mmscmd by FY20.

In the backdrop of rising demand and shortage in domestic gas supplies, LNG is likely to assume an important role in meeting the gas shortfall. CRIS expects the share of LNG in the overall gas supplies to rise to around 70% by FY40, as against 20% being contributed currently, unless some new big fields are discovered in India.

To benefit from the rising demand for LNG, HEGPL has planned to set up the Project of setting up an 8 MMTPA LNG import terminal at Jaigarh Port in Maharashtra by entering into a sub-concession agreement with JSWJPL. CRISIL has identified the specific markets where the re-gasified LNG (RLNG) can be supplied through the LNG re-gasification terminal. The Project is based on tolling model where the end users or gas marketing companies may directly procure LNG from international suppliers and use re-gasification and storage capacity in the LNG terminal.

In order to determine the catchment area for the project, CRISIL has considered the competiveness of delivering LNG from various existing and planned LNG terminals in India. Based on this method, nearly 337 districts were shortlisted across the states of Gujarat, Rajasthan, Haryana, Maharashtra, Madhya Pradesh, Chhattisgarh, Jharkhand, Bihar, Uttar Pradesh, Delhi, Uttarakhand, Kerala, Goa and Karnataka. Notably, the catchment area is large for the proposed project. This is due to the business model being proposed by HEGPL, which will allow direct sale purchase of LNG between the end-consumer at retail level and LNG seller.

1.5 PURPOSE OF THE REPORT

MoEF&CC vide letter dated 19th December, 2013 issued the environmental and CRZ clearance for expansion of of the port. The proposal for the introduction of a FSRU (6 MTPA) in early production phase was presented to the EAC (Infra-2) in their 10th Meeting held on 24th October, 2016. The EAC exempted the Project Proponent from preparation of the EIA-EMP report as well as the Public Hearing as there was no change in plant capacity. However, the EAC recommended a detailed marine, estuarine and creek impact assessment report and management plan through an institute of repute on marine ecology and biodiversity that should include intertidal biotopes, corals and coral communities, sea grasses and seaweeds, sub tidal habitats, fishes and other marine flora and fauna including, turtles, birds and marine animals inclusive of mammals.

The present Report is prepared to meet the requirements of the recommendation of the EAC referred in the preceding paragraph.

The Report establishes the prevailing ecological status of the marine and estuarine environment based on field studies with respect to water quality, sediment quality, biological characteristics and their comparison with historical data wherever available. The report also analyses probable environmental perturbation due to the proposed FSRU and related activities at JSW Jaigarh Port. Jaigarh Based on the assessment of impacts, mitigation measures to minimize these impacts in terms of a structured Environment Management Plan (EMP) are suggested.

1.6 IDENTIFICATION OF PROJECT AND PROJECT PROPONENT

1.6.1 IDENTIFICATION OF THE PROJECT

In Phase I, it is proposed to have a FSRU at JSW Jaigarh Port Jaigarh. The regasification and the storage unit will be located on the FSRU moored at the LNG jetty in Jaigarh Port while the waterfront structures will remain identical. FSRU will receive LNG by ship to ship transfer via cryogenic flexible hoses from a LNG carrier (LNGC) which will be moored alongside the FSRU. The FSRU will store, pressurize and re-gasify the LNG. The high pressure natural gas will be exported from the FSRU via articulated High Pressure Gas Loading Arms mounted on one of the Breasting Dolphins at the jetty head and transported via a gas pipe from the jetty to the onshore terminal area where gas meters and pig launching facilities will be located. From there the gas will flow via the 60 km gas pipeline to Dabhol receiving facility and supply to consumers through-gas distribution grid.

In Phase II the Terminal will comprise of jetty based LNG unloading facilities to accommodate LNG ships, LNG transfer pipelines, two 190,000 m^3 (net capacity) full containment LNG storage tanks fitted with in-tank LP LNG pumps, a boil off gas recovery system, HP LNG pumps and Ambient Air Heater based IFVs for LNG vaporization system . The electrical supply for the Terminal will be provided from dedicated Gas Engine Generators located within the Terminal.

As stated above the Phase II operation consisting of the land based permanent facility has already received the environmental clearance.

1.6.2 PROJECT PROPONENT

JSW GROUP Profile

JSW Group is one of the fastest growing business conglomerates with a strong presence in the core economic sector. This enterprise has grown from a steel rolling mill in 1982 to a multi business conglomerate worth US $ 11.0 billion within a short span of time.

As part of the US $ 16.5 billion O. P. Jindal Group, JSW Group has diversified interests in Steel, Energy, Minerals and Mining, Aluminium, Infrastructure, Cement and Information Technology.

JSW Steel Limited (JSWSL), the flag ship company of JSW group is one of the largest steel producers of the Country. The company has manufacturing facilities located at Vijayanagar in Karnataka, Salem in Tamil Nadu, and Vasind, Tarapur, Dolvi, & Kalmeshwar in Maharashtra. JSW Steel has present capacity to produce steel of 18.0 million tonnes per annum (MTPA). The group presently engaged in the fields of steel, cement and aluminium production, power generation and Infrastructure development.

JSW Steel at Vijayanagar is one of the India's largest integrated steel company with an annual capacity of about 10.0 MTPA. The company has manufacturing facilities located at Vijayanagar in Karnataka, Salem in Tamil Nadu, Vasind, Tarapur and Dolvi in Maharashtra. The product range includes Pellets, Slabs, HRC, HR Plates / Sheets, CR Coils, GP/GC and Colour Coated Coils/Sheets, Bars, Rounds and Reinforcement bars.

JSW Energy Ltd. (JSWEL) is the first Independent Power Producer (IPP) set up in the state of Karnataka. The company has set up 2 units of 130 MW each and two units of 300 MW each and all these units are generating power using Corex gas and coal. JSWEL supply power to JSW Steel Ltd., and to Power Trading Corporation. JSWEL requires 4 MTPA of coal for its 1200 MW power plant at Vijayanagar.

Another subsidiary, JSW Energy (Ratnagiri) Ltd, is operating a 1200 MW Coal fired power plant at Jaigarh, District, Ratnagiri, Maharashtra. Another unit is functional at Barmer, Rajasthan producing about 1080 MW lignite fired power.

The JSW Infrastructure Ltd. (JSWIL) is a JSW Group company which is presently into development of ports, rail/road and inland water connectivity, development of port based SEZ and other related infrastructure developments works along with terminal handling operations and port management.

Buoyed by the Group's cargo support, experience in marine infrastructure development and operations, JSWIL ventured into development of Greenfield ports across the coast of India.

South West Port Ltd. (SWPL), a JSWIL group company, has developed two berths, namely berth no. 5A & 6A in Murmugao Port, Goa on BOOT basis. SWPL with a present capacity of 7.5 MTPA is expanding to handle cargoes of about 15.0 MTPA by deploying highly mechanized and environment friendly equipments.

JSW Jaigarh Port Ltd. (JSWJPL), a subsidiary of JSW Infrastructure Ltd. developed as Greenfield all weather Port facility at Jaigarh in Ratnagiri Dist. by entering a 50 year concession agreement with the Maharashtra Maritime Board (MMB). Presently, Jaigarh Port is undergoing a major expansion plan in its second phase.

In the initial Phase, the Port has an installed capacity of about 10 MTPA of dry and liquid cargo. JSWJPL is meeting the coal requirements of the operational 1200 MW power plant of JSW Energy in its first phase. In the second phase expansion, the port has planned to handle other cargoes like bauxite, raw sugar, fly ash, cement, iron ore, fertilizers, fertilizer raw materials, edible oil, molasses and chemicals, containerized cargoes, POL and LNG. Rail, road and inland waterway connectivity projects for the port are also being taken up simultaneously to propel the growth further by connecting the port seamlessly with the hinterland. The LNG facility is being developed by H-Energy Gateway Private Limited (HEGPL), Mumbai.

JSW Dharamtar Port Ltd., another subsidiary of JSW Infrastructure Ltd.at Dolvi in Raigad District of Maharashtra, is an existing port and terminal facility, located in Amba River about 23 Nautical Miles away from Mumbai Harbour by sea route. The port has 331.5 m jetty with a depth of 4.5 metres, capacity to handle about 8.0 million tonnes per annum of cargo. The port facility is being expanded with construction of additional jetty length up to 1750 m in phases to handle various cargoes about 35.0 million tonnes per annum.

JSW Dharamtar Port can handle bulk and break-bulk cargo. The Port currently handle entire import & part of export requirement of JSW Steel Plant at Dolvi in Maharashtra. The cargo handled includes limestone pellets and lumps, dolomite, hot briquette iron, sponge iron, PCI coal, scrap, and iron ore lumps, fines and pellets. Dharamtar Port currently looks after JSW Group's Dolvi and Kalmeshwar Steel Plants' export-import (EXIM) requirements.

HEGPL Profile

H-Energy Gateway Private Limited (HEGPL); erstwhile Hiranandani Gas Company Private Limited, has entered into the clean energy infrastructure developments recently. To benefit from the rising demand for LNG, HEGPL has planned to set up the Project of setting up an 8 MMTPA LNG import terminal at Jaigarh Port in Maharashtra by entering into a sub-concession agreement with JSWJPL. The Project is based on tolling model where the end users or gas marketing companies may directly procure LNG from international suppliers and use re-gasification and storage capacity in the LNG terminal.

1.7 JAIGARH PORT AND PROPOSED DEVELOPMENT

1.7.1 ONSHORE MARINE FACILITIES

Jaigarh Port is operational with the following features as part of the first phase of development and expansion phase:

- Berths 1 and 2 with a total length of 550 m.
- Berth 3A length 306 m
- Berth 6A 343 m
- Breakwater 700 m long.
- Approach Channel deepened to -19.8 m CD to suit ship sizes of 180,000 DWT
- Coal Handling Facilities at Berth 1 rated for 4000 TPH (ship unloading) to support the requirements of the Power Plant operated by JSW Energy.
- Miscellaneous cargo handling at Berth 2 rated at 2500 TPH
- Coal/Iron Ore handling on Berth 3A at rated capacity of 6500 (3250x2) TPH
- Iron ore/Coal loading at berth 6A 16000 (2500x4+1500x4)TPH (Iron Ore)

The Port is under expansion to develop additional facilities required to handle various solid and liquid cargoes:

- Development of additional berths Import of Coal
- Import of other bulk : Fertilizers, Raw Sugar and Limestone
- Export of Bauxite and/or Iron Ore
- Export of Iron and Steel Products
- Import and Export of Containerized Cargo
- Import of POL and Edible Oil
- Import of LPG
- Import of LNG
- Export of Passenger Cars and other Vehicles
- Barge Loading of Fly Ash generated at the JSW Energy Power Plant based on the projected traffic.

Figure 1.2: Lay out of Jaigarh Port

According to port, location shown in the above figure is considered as most ideal for LNG operations.

1.7.2 OFFSHORE MARINE FACILITIES

Dimensions will be maintained as shown below: (All depths are with respect to chart datum (CD), unless otherwise specified)

Channel width :	Present: 250 m Future: 315 m
Channel depth - Outer : Inner :	 -19.50 m CD -19.20 m CD
Turning Circle diameter:	Present: 600 m Future: 700 m
Turning Circle depth:	-19.20 m.CD
Depth at Berth 1 & 2:	-19.50 m CD
Depth at other berths:	-19.50 m CD
Depth at LNG Berth	-15.00 m CD

1.7.3 BREAKWATER

A 542 m long breakwater with a 6 m wide roadway on top which ends in a 20 m diameter circular turning pad at the breakwater head was constructed in Phase I as dictated by the model studies. The breakwater was extended by 700 m to provide additional tranquillity for the port on account of the waves from the NW.

Precast concrete “Accropode” armour units were used as armour layer. This is a single layer armour system which saves a considerable quantity of concrete as well as placement time compared with a two layer system. The primary armour rested on secondary rock armour (placed in two layers) which in turn will rest on a core material of 10 to 100 kg., size. A side slope of 1:1.33 and 1:1.5 as applicable were provided. The head of the breakwater is so located as to ensure a 10 m wide berm between its toe and the slope line of the dredged channel of future. Breakwater core was constructed by barge dumping up to an elevation of about –3 M CD and then followed by end dumping. Armoring will be placed by cranes from breakwater embankment as well as from floating craft. The breakwater has been designed for a design wave height of 7.5 m with a return period of 100 years as established by the mathematical model study.

1.7.4 BERTHING AND UNLOADING OPERATION FACILITIES

The major components of the marine facilities specific to the LNG Jetty are:

- The jetty head (unloading platform) and access trestle,
- The breasting and mooring dolphins,
- The mooring equipment,

The ships will berth at a jetty. Two (2) breasting dolphins with fenders are placed at each side of the Unloading Platform of 55 m x 38 m. They will be fitted with hooks to make-fast the spring lines of the ship. The spacing of the breasting dolphins is such as to provide a breasting face between 25% and 40% of the ships overall length. Six (6) mooring dolphins are foreseen to make-fast breast lines, headlines and stern lines. All breasting and mooring dolphins are fitted with quick release mooring hooks. The Jetty head and approach trestle, and LNG carrier berthing components are part of the overall work scope necessary for the development of the LNG Import Terminal. The LNG jetty shall be designed to accommodate LNG carriers in the size range of 90,000 m^3 to 270,000 m^3. To accomplish this, the LNG berth will include breasting and port mooring dolphins, fender systems, mooring hooks, mooring line tension monitoring system, berth aid system including weather monitoring system and the gangway for ship-shore access as a minimum.

Another major objective of the LNG berth is to provide a platform to support the mechanical equipment required for unloading LNG carriers. The

LNG trestle shall provide structural support from the shore to the LNG unloading platform for the LNG unloading piping, auxiliary mechanical and utilities, control and electrical systems, and access roadway.

1.7.5 BRIEF DESCRIPTION OF THE PROJECT AND ITS IMPORTANCE

To bring the supply of natural gas produced from around the world to the major gas markets, which are usually located a long distance away, natural gas is either transported to market by a long distance pipeline or converted into LNG and then transported to market by a special purpose LNGC. The LNGC receives its LNG cargo at an LNG liquefaction plant in an exporting country and then delivers this LNG to the importing country, and the LNG is FSRU technology has developed and matured over the recent years, and has been chosen as a viable and cost effective design where constraints exist concerning large land-based LNG receiving facilities. At the gas producing country, the process of LNG production involves the transport of the natural gas from the production fields via pipeline to a liquefaction plant. Prior to liquefaction, the gas is treated to remove contaminants, such as carbon dioxide, water and sulphur to avoid them freezing and damaging equipment when the gas is cooled to -162°C where it enters its liquid state. The LNG produced from the liquefaction process is piped into LNG storage tanks. Both the pipes and LNG storage tanks are insulated to maintain the low temperature. LNG storage tanks are designed and constructed using special materials to contain the cryogenic liquid. LNG is then pumped from the LNG storage tanks, and loaded onto the specially equipped LNGCs and transported to the LNG importing countries. When the LNGCs arrive at the place of import, LNG is unloaded onto the FSRU facility where it is stored on board the FSRU vessel in its LNG storage tanks. Then, to meet local gas demand, the LNG is re-gasified and piped to end-users, such as power plants and major industries.

It is believed that the LNG terminal project shall have positive impact on local community by creation of direct & indirect jobs. The project may also potentially fuel the economic development of the region by promotion of Industries in the core & adjoining areas. Given the need for sustainable development, it is today the endeavor of the industry & the policy makers to promote projects which have least environmental impact; positive social benefits; and potential to assist in overall development of nation. HEGPL LNG terminal is such a project & the construction of the LNG terminal would bring in general prosperity in area and would serve not only the local but also the nation as a whole. The economic activity will take a boost & there will be direct & indirect employment generation. Supporting facilities created as a part of the LNG terminal would also benefit the local community.

1.8 TERMS OF REFERENCE (TOR)

In the 10th meeting of Expert Appraisal Committee (Infra-2) on 24-25 October, 2016 sought the following project specific information:

(i) Certified compliance report on the environmental conditions stipulated in the earlier E.C. issued by the Regional Office, MoEF & CC.

(ii) Submit a copy of layout superimposed on the HTL/LTL map demarcated by an authorized agency on 1:4000 scale.

(iii) Recommendation of the SCZMA.

(iv) Apart from the terrestrial and fresh water biodiversity surveys, a detailed marine, estuarine and creek impact assessment report and management plan, as applicable, shall be drawn up through the NIOS or any other institute of repute on marine ecology and biodiversity. The report, to cover activities at the Jaigarh port and also the activities related to the proposed storage, shall study the intertidal biotopes, corals and coral communities, sea grasses and seaweeds, sub tidal habitats, fishes and other marine flora and fauna including, turtles, birds and marine animals inclusive of mammals. Data collection and impact assessment shall be as per standard survey methods.

(v) Tranquillity and Mathematical Model study.

(vi) Study for cold water dispersion. Special mention shall be made of the difference in temperatures in the sea water through discharge of used sea water. Action plan and the monitoring mechanism to control the discharge (COLD WATER) temperature within 3 degree centigrade from the ambient as per the UNO guidelines.

(vii) Anticipated impacts due to THERMAL SHOCK and the mitigation measures.

(viii) Environmental Management Plan and Environmental Monitoring Plan.

(ix) Risk Assessment for FSRU & Disaster Management Plan

- Identification of hazards
- Consequence Analysis
- Details of domino effect of the storage tanks and respective preventive Measures including distance between storage units in an isolated storage Facility.
- An onsite disaster management plan shall be drawn up as per law and Dovetailed with the offsite management plan for the district.

(x) Accreditation proof of the international consultant DNUGL, who had prepared the QRA report and commitment for compliance of QRA recommendations.

1.8.1 SCOPE OF WORK PROPOSED BY CSIR-NIO

The CSIR-NIO suggested the following Scope of Work for conducting the marine-related studies with focus on ecological and biodiversity studies vis-à-vis the proposed FSRU project.

1.8.1.1 OBJECTIVES

a) To establish the prevailing hydrodynamics and ecological status of the proposed FSRU site and the estuarine area.
b) To assess probable impact of proposed ambient seawater intake and cold & hot water outfall on coastal ecology.
c) To recommend suitable environmental management plan to minimize any adverse impact on marine biota.
d) To recommend environmental monitoring plan.

1.8.1.2 DATA COLLECTION

One season (pre monsoon) primary data was collected at selected subtidal sites and incorporating any such parameter as required by MoEF&CC in the approved ToR. Secondary data (already available with CSIR-NIO) will also be used in assessing broad environmental trends in the study area.

1.8.1.3 MONITORING PARAMETERS

The environmental parameters proposed to be monitored in the study area are given below:

Physical parameters: Tides and current was measured by mooring the tide gauge and current meter at pre-decided location. Water circulation pattern will be evaluated deploying and following a drogue.

Water quality: Marine and estuarine water quality was assessed in the subtidal areas and also at surface and bottom when water depth exceeded 5 m. Data on the following parameters were studied: Temperature, salinity, Suspended Solids (SS), pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), phosphate, nitrate, nitrite, ammonia, Petroleum Hydrocarbons (PHc), phenols and pathogenic bacteria.

Sediment quality: Sediment quality was assessed in the subtidal areas in terms of texture, organic carbon, phosphorus, PHc and selected metals, (aluminium, chromium, manganese, iron, cobalt, nickel, copper, zinc, lead, cadmium and mercury).

Flora and fauna: Phytoplankton population and generic diversity; primary productivity; zooplankton standing stock; macrobenthic standing stock subtidal regions; mangroves and their diversity; corals and their diversity; marine reptiles; marine mammals and sea birds was investigated. Fishery of the region was assessed based on data from the Department of Fisheries, Government of Maharashtra as well as the results of the experimental trawling.

Modelling: The change in hydrodynamics and the impact of FRSU operations on near-shore ecology was delineated using a 3D numerical model from the inputs generated during field observations.

1.8.1.4 DESCRIPTION OF MARINE ENVIRONMENT

The data obtained during field studies was used to assess the prevailing estuarine and marine environment off Jaigarh. The results were compared with the earlier data available with CSIR-NIO of the same area.

1.8.1.5 ANTICIPATED ENVIRONMENTAL IMPACT AND MITIGATION MEASURES

Based on the project information made available by JSW/H-Energy and the prevailing estuarine and marine environmental condition, probable environmental impacts particularly on water quality, sediment quality and flora and fauna was evaluated during construction and operational phases of the FSRU project. Adequate mitigation measures have been suggested to minimize these impacts on coastal ecology of the region.

1.8.1.6 ENVIRONMENTAL MANAGEMENT PLAN (EMP)

In the conceptual EMP mitigation measures are suggested to minimize the impact of the proposed FSRU on coastal ecology.

1.8.1.7 FIELD DATA COLLECTION

Field data in the proposed FSRU region, Shastri Estuary and the adjacent marine zone was collected during March 2017 (Premonsoon season).

1.9 APPROACH

Some negative impacts of a developmental activity in the coastal zone on aquatic ecology are generally inevitable. The intensity and duration of negative impacts depend on a number of factors.

In planned projects, these impacts are identified in order to take suitable mitigation measures in the planning itself through systematic environmental studies. Hence, identification of impacts require detailed collection of data and reliable information on water quality, sediment quality, biological characteristics and physical processes of the project site against which perturbations, if any, due to the development can be compared and changes delineated.

1.9.1 ESTUARINE AND MARINE ENVIRONMENTAL DATA STATUS

Jaigarh is a small fishing village and a natural harbour at the mouth of the Shastri River in the Ratnagiri District. Shastri River rises in the Sahyadris and flows westward before meeting the sea near Jaigarh. The tidal impact through the estuary is up to Sangameshwar and during this course several small rivers meet and join the Shastri. Shastri Estuary has two bays viz. Dhamankhol Bay (depths of 7 to 8 m) and Jaigarh Harbour (depths of 12 to 13 m) inside the harbour but has a sand bar at the entrance. The confluence of the Shastri River and the Arabian Sea is called the Jaigarh Creek. The inner estuarine region has good mangroves vegetation. Presently the estuary does not receive any known point discharge of wastewater. A coal based power plant of JSW Energy is operational in the vicinity since 2009. To meet the coal JSW Energy and iron ore requirement for its Dharamtar steel plant, a JSW, Jiagarh Port is operational in Damankul Bay, Jaigarh.

CSIR-NIO has undertaken several investigations in the area between 2007 and 2016 and relevant ecosystem health parameters such as water quality, sediment characteristics and coastal ecology have been studied. Thus, CSIR-NIO has the seasonal data-sets pertaining to the following periods on the coastal environment:

- March 2007 and 2016
- December 2007
- January 2016

These data would facilitate assessment of overall progressive status of ecology of the area and changes taken place in the due course of time.

The region is under monsoon spell during June-September which could also induce changes in hydrography and ecology. Field studies in the coastal region are difficult during this period because of hostile weather conditions. In fact monsoon period is not critical from the point of view of environmental degradation due to anthropogenic influences, since turbulence and high land runoff results in faster dispersal of pollutants, reducing the impacts of external perturbations on ecology. Field data collection was successfully completed in the estuary as well as offshore during March 2017.

1.9.2 PROPOSED DEVELOPMENT AND CRZ NOTIFICATION – 2011

Ministry of Environment Forest & Climate Change (MoEF & CC) vide letter dated 19th December 2013 has issued environmental and CRZ clearance to M/s JSWV Jaigarh Port Ltd. For expansion of JSW port at Jaigarh, Ratnagiri, Maharashtra. Further, MoEF& CC vide letter dated 3.3.2015 has transferred the environmental clearance & CRZ clearance from JSW Jaigarh Port to M/s H Energy Gateway Pvt. Ltd. The clearance includes 8 MTPA shore tankage based LNG terminal. The clearance includes 8 MTPA shore tankage based LNG receiving terminal, re-gasification and send-out facility.

2. PROJECT DESCRIPTION

The information mainly provided by the project proponent is presented in this section.

H-Energy Gateway Private Limited (HEGPL) is planning to design, construct and operate an 8 million tonne per annum Liquefied Natural Gas (LNG) Storage & Regasification Terminal (the "Project") at Jaigarh on the west coast of India in Maharashtra. The project is in close proximity to GAIL's Dahej-Uran-Panvel-Dabhol-Gas Pipeline (DUPL), as well as Dabhol-Bangalore Natural Gas Pipeline (DBPL).

The decision to build a terminal at the chosen location follows a series of studies including an in-depth market analysis to assess the demand for LNG/ Natural Gas and a detailed Front End Engineering Design (FEED) study to ascertain the technical feasibility, sustainability, safety, risk and the social & environmental impact of construction & operations of the facility.

A summary of the proposed development is tabulated below. This development was the subject of an earlier EIA submission. Environmental Clearance for the project was received by JSWJPL and transferred to HEGPL.

1. Main Terminal Components/ Features :	
Marine Infrastructure & Port Facilities	Existing Navigational Channel and Breakwater Protected Harbour with available depth of -19.2 m Chart Datum (CD) & proposed Berthing facilities for up to Qmax (267,000 m^3) LNG Vessels
Unloading Facilities	4 x 16" Unloading Arms each with a maximum design capacity of 4900 m^3/hr 1 vapour return line of capacity 15000 m3 / hr 44" Single Unloading Line designed for a maximum flow rate of 15,000 m^3/hr
Storage Facilities	2 x 190,000 m^3 (net capacity) full containment LNG storage tanks, with provision for future expansion to add one more similar tank. 3 x LP Pumps per tank for send out to HP pumps 3 x BOG (Boil Off Gas) Compressors & 1 Recondenser for BOG Recovery

	6 x HP pumps for send out to vaporizer system
LNG Truck Loading Facilities	4 truck loading bays with provision for additional 4 similar bays for future expansion
Regasification Facilities	4 x Intermediate Fluid Vaporisers with Air Heaters and glycol/ water heat transfer fluid. Provision for 5th Vaporiser
Evacuation Infrastructure	Metering & Regulating Station + truck loading+ 60 km gas pipeline connecting to GAIL's pipeline network at Dabhol
2. Power Generation:	4 x Engine Generators (3 Gas Based & 1 Dual Fuel) - Three (3) x 33% Engine Generators in operation and One (1) 33% Engine Generator in standby 1 x Emergency Diesel Generator for 100 % Backup for emergency load
3. Utilities :	
Fresh Water	Atmospheric condensed water from the air heaters shall be used for service water and fire water. Potable water supplied by water tankers will be used for potable needs.
Fire Water	Exclusive 25,000 m^3 Freshwater Pond for a minimum of 4 hours of fire fighting.
Instrument & Plant Air	Air compressors & drier for continuous operation
Nitrogen	Liquid Nitrogen storage & vaporization facility
Fuel Gas	Sourced from RLNG / BOG
Diesel Oil	Required for Diesel Generators & backup systems
4. Control & Monitoring :	A dedicated Plant Control System shall be designed & implemented.
5. Project Schedule :	44 months (from Notice to Proceed issued to Engineering Procurement and Construction (EPC) Contractor until start of operations)

Based on market dynamics it has been decided to implement the project in a phased manner as follows -

Phase – 1: Early Production Facility (EPF) using leased LNG Floating Storage and Re-gasification Unit (FSRU) and Tie-in gas pipeline from Jaigarh to Dabhol and connection to the GAIL (India) Limited pipelines.

Phase –2: Land based LNG terminal including LNG storage tanks and regasification facilities and gas pipeline from Jaigarh to Mangalore.

Phase 1 will be based on a reduced scope of facilities aimed at delivering 3-4 MMTPA of regasified LNG to reduce the project schedule (time to market) and more closely match the projected sales forecast for gas.

Phase 1 of the Project will utilize Early Production Facilities (EPF) with the intent that the facilities to be installed will be minimized. The design will be based on a leased Floating Storage Regasification Unit (FSRU), which is essentially a LNG Carrier ship (LNGC) with High Pressure pumps and vaporization and gas send out facilities installed. The FSRU will be moored at the LNG Jetty, within Jaigarh Port. (The Jetty built in Phase 1 will also be utilized in Phase 2). The FSRU will receive LNG by Ship to Ship transfer from LNG Carriers (LNGC), which will moor side by side to the FSRU. LNG will be transferred from the LNGC to the FSRU via cryogenic flexible hoses. The FSRU will store, pressurize and re-gasify the LNG. The high pressure natural gas will be exported from the FSRU via articulated High Pressure Gas Unloading Arms mounted on one of the Breasting Dolphins near the jetty head and be transported via a gas pipeline from the jetty to the onshore terminal area (a distance of approximately 1 km), where gas meters and pig launching facilities will be located. From there the gas will flow via approx. 60 km gas pipeline to Dabhol.

Phase -1 shall be followed by the permanent Phase 2 facilities. Phase 2 facilities are as tabulated above. Comparative schematic of Phase – 1 and Phase – 2 is shown in Figure 2.2.

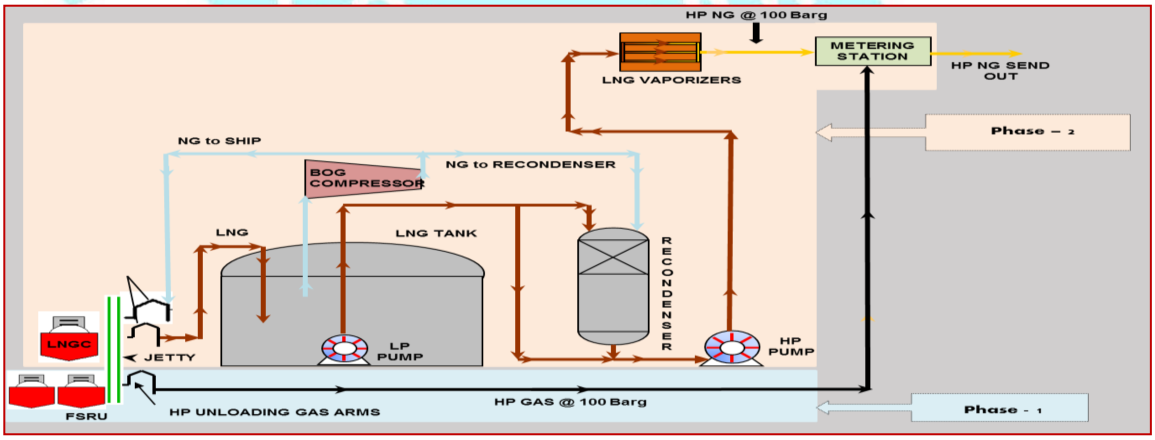


Figure 2.1: Schematic Phase - 1 and Phase - 2

The following sections describe the Phase 1 facilities in more detail. Phase – 1 facility is scheduled to be operational by Q2 - 2018.

Refer Annexure – I for Key Plan of EPF on Satellite Image

The simplified process flow diagram of the Phase 1 FSRU and Jaigarh Onshore Receiving Facilities is shown in Figure 2.3.

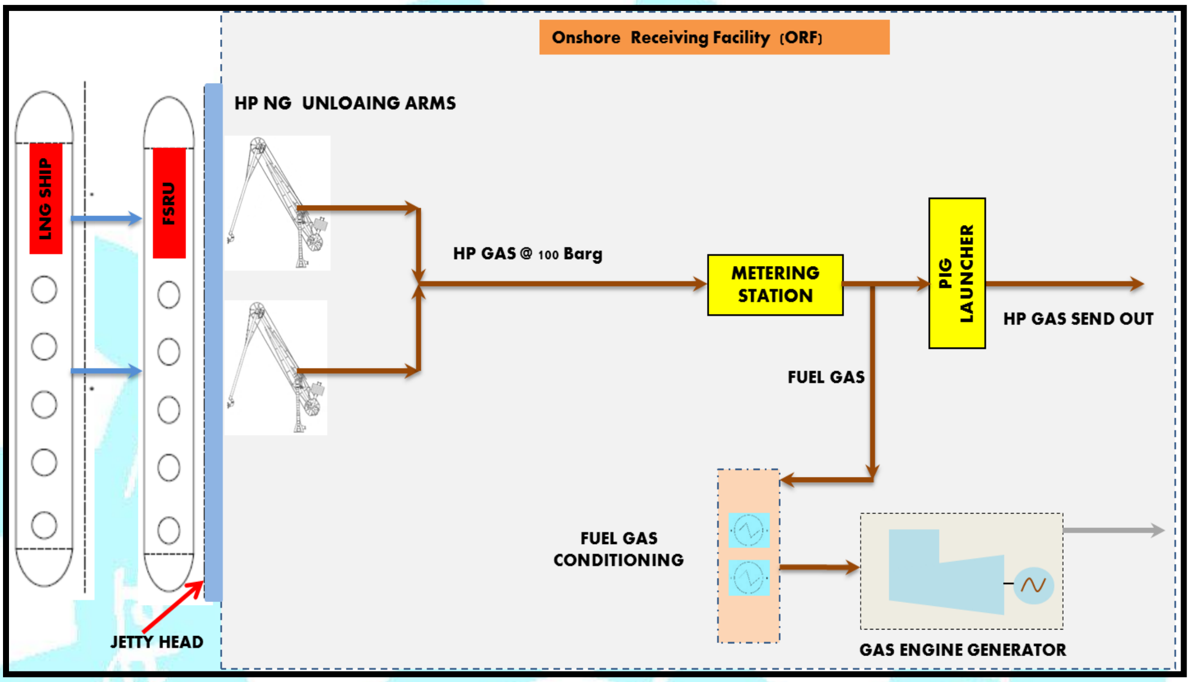


Figure 2.2: Simplified Process Flow Diagram Phase 1 (EPF)

2.1 LNG STORAGE AND VAPOURISERS FSRU CONCEPT

A jetty moored FSRU which is a well proven technology worldwide with several references across the globe has been selected as the preferred option for the EPF. This has the potential to defer the maximum amount of Capex, and virtually all the facilities are provided on the leased vessel. The FSRU is essentially a conventional LNG Carrier with additional LNG vaporization & send-out facilities installed on the main deck.

The send-out facilities include HP send out pumps, vapour re-condenser which operates during send out to re-condense low pressure Boil-off Gas to allow it to be pumped and then vaporized for export. The vaporizers may use one of several vaporizer technologies but the most common used by recently built vessels is the so called open loop system, where seawater is used on a once through basis to provide the heat for the vaporization. Typically an intermediate fluid is used to transfer heat from the seawater to the LNG; this is to reduce the risk of the seawater freezing. The intermediate fluid may be

Propane, or a glycol/water mixture. These open loop designs minimize operating cost as the energy for vaporization is obtained from the sea water. However this design requires large quantities of seawater to be lifted and discharged.

In some cases the vaporization is performed in a closed loop heating system. In these systems fuel gas (e.g. Boil-off Gas) is used as the energy source to vaporize the LNG. Typically the gas is burned in boilers to produce steam and this is used to vaporize the LNG. This design has the advantage that it does not require sea water. However the cost of the gas consumed is very significant and therefore a careful evaluation of the options is required.

It is with the above factors in mind, HEGPL intend to retain both the options and the selection shall be based on commercial evaluation, at any time during the operation.

FSRU's may be either converted existing LNG Carriers, or can be purpose built vessels. Both the construction approaches are acceptable and proposals for both options will be evaluated.

A cutaway image of a typical "Conversion" FSRU is shown below

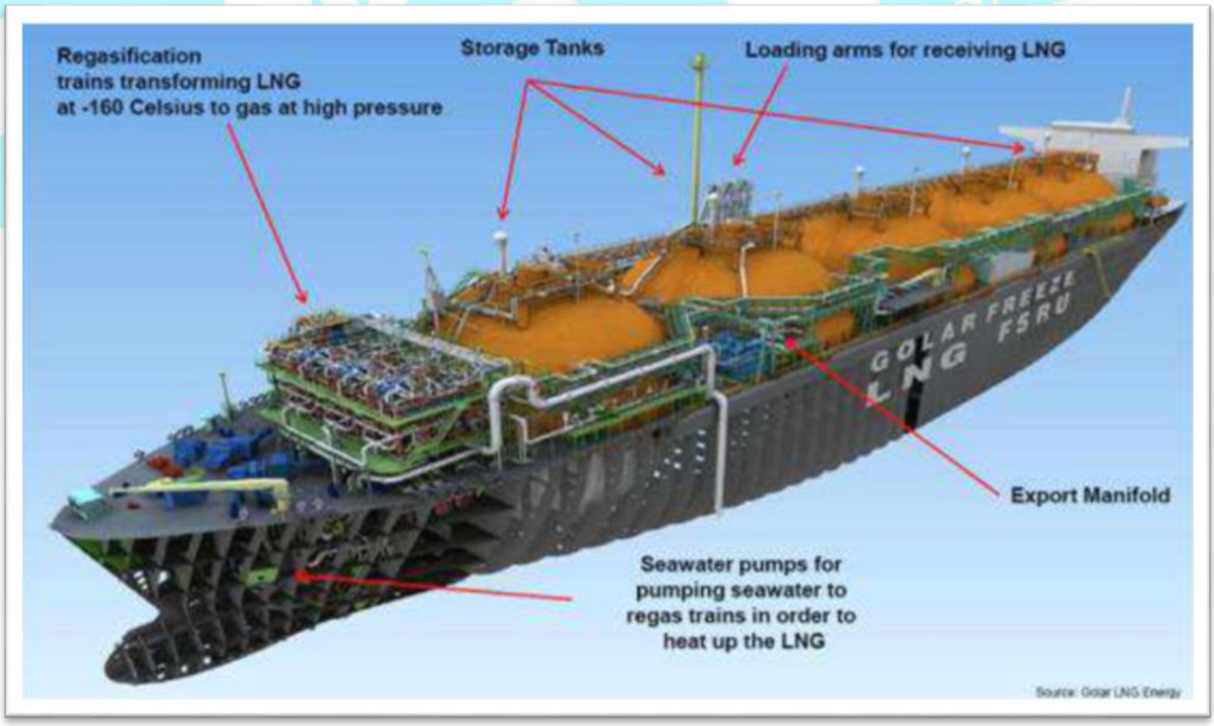


Figure 2.3: Typical FSRU Schematic

A photo of a typical FSRU on station, connected to High pressure Gas Unloading Arms on Breasting Dolphin is shown below.

Figure 2.4: Typical FSRU On Station

The Design Layout for the Jaigarh LNG jetty facilities is shown below:

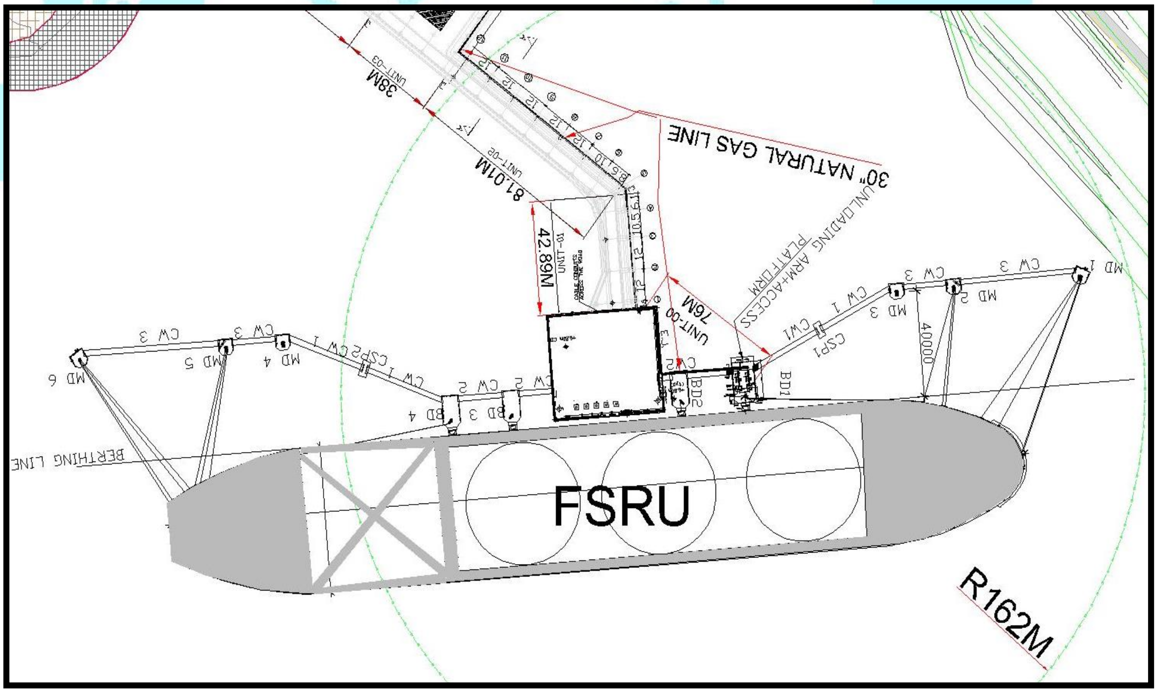


Figure 2.5: Conceptual Design Layout

2.2 FACILITIES DESCRIPTION

As described above, the selected option for Phase 1 (Early Production Facilities) is to lease an FSRU which would be moored at the jetty head. Approximately 60 km long gas pipeline would also be constructed to evacuate the gas to Dabhol. The facilities designs for the selected design option are described below in more detail.

The following Figures shows the layout of the Jaigarh Port, highlighting the location of the proposed LNG Jetty/ FSRU and the Onshore Receiving facilities (Figure 1.2)

Approximately 10 Acres of land has been secured to allow the establishment of the Phase 1 facilities. For Phase 2; approximately 85 acres project area will be made available by JSWJPL.

2.3 FSRU AND ON-BOARD FACILITIES

The FSRU will be initially leased on a day rates basis for 5 to 10 year term. The FSRU will be selected from vessels available in the market as of Q1 2019. The FSRU will be selected based on a competitive commercial tender, and hence the specific configuration of the vessel and its equipment are not known at this stage. The selected FSRU shall comply with applicable IMO regulations, Industry specific guidelines such as from SIGTTO, ISGOTT, SOLAS, MARPOL, PIANC, OCIMF and DGS guidelines.

The description below is typical of several vessels that are currently either under construction or planned for conversion, which HEGPL is evaluating at present.

The FSRU will be equipped with all facilities and equipment to allow it to operate independently as an LNGC or FSRU. In addition to the storage tanks, it will be equipped with all marine systems including Duel Fuel Diesel Electric main engines, power generation, Cargo loading and unloading facilities such as cryogenic Ship to Ship transfer hoses, BOG compression, BOG Recondenser, all necessary utilities including fuel gas, nitrogen, inert gas, diesel fuel system, ballast water systems, water makers, fire water systems. It will also be equipped with high pressure LNG booster pumps and Vaporisers to allow send out of gas at approximately 100 – 115 Barg pressure.

Gas Send-Out

The FSRU shall be capable of providing the following export gas rates:

- Normal continuous supply (associated with redundancy): 500 MMSCFD
- Maximum continuous supply (peak rate with no redundancy): 750 MMSCFD

Gas Send-Out Conditions

The FSRU will be designed to meet a maximum pressure of 120 barg at the FRSU discharge flange. The natural gas send out temperature will be minimum 0^0C for the desired range of LNG compositions with normal working pressure varying between 50 barg to 100 barg and with minimum 10^0C seawater temperature in open loop system. The natural gas send out temperature can be increased with warmer seawater temperatures; this can to be adjusted to meet the operational requirements.

Regasification system

The regasification system will be installed at the front of the FSRU. The main supply of LNG to the regasification system will be made by 4 production pumps (one fitted in each cargo tank) which will deliver LNG into the production header. The production pumps are designed for continuous service and fitted in the cargo tank emergency pump well. The production header will run from the aft cargo tank to the tie-in-point at the regasification system, which will be installed on main deck fwd of the foremost cargo tank.

The high pressure natural gas from the four regasification trains will be led to the high pressure manifold (about 30 to 60 meters fwd of the LNG loading manifold) through the high pressure discharge pipe. This high pressure line can be fitted with fiscal metering and over-pressure shutdown valves to protect the downstream system from excess pressure if this is required.

The high pressure manifold will be located on the Port side and the LNG loading hoses on the Starboard side of the FSRU. Regasification process on board the FSRU can be summarized by the following system diagram:

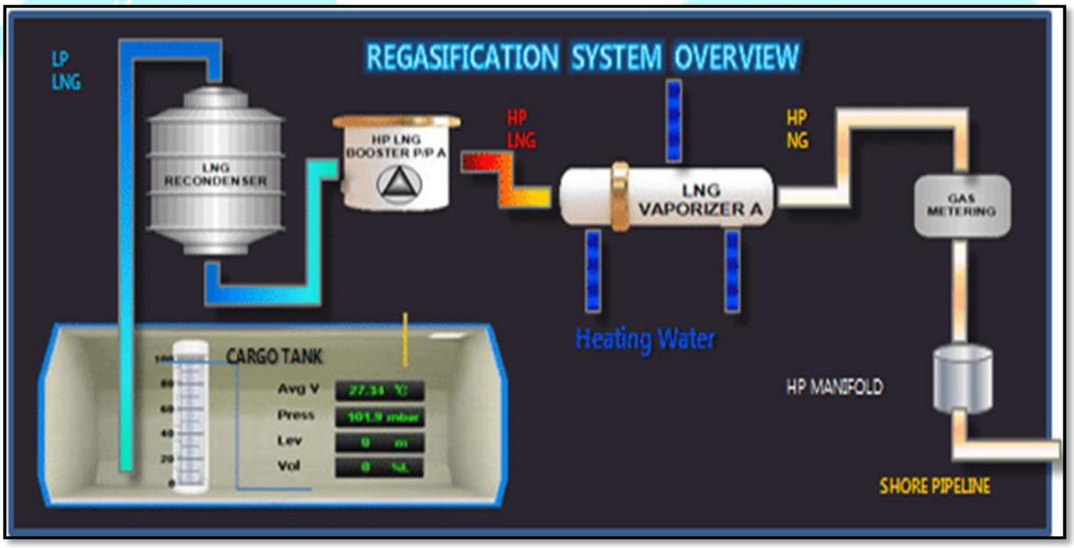


Figure 2.6: Typical FSRU Regasification System Overview

HP LNG Booster Pumps

The high duty LNG booster pumps are high pressure cryogenic centrifugal pumps fully submerged and operated at fixed speed. Flow (and pressure) control is performed by means of throttling on the pump discharge. Hence pump selection is made, based on the maximum required send-out flow and pressure at the lowest design LNG density. Natural gas send-out pressure range is determined according to project requirements, including LNG design compositions. Within the natural gas send-out pressure range the flow can be varied between 40 and 100 % of the LNG booster pumps flow capacity. The high pressure booster pumps increase the pressure to meet the send out pressure.

LNG Vaporizer

Downstream the high pressure booster pumps, the LNG is fed to the vaporisers where the temperature is increased to meet the 0 degree C minimum at the FSRU send out battery limit. The LNG is vaporized and heated in LNG vaporizers, using a water/glycol mixture as heating medium that runs in a closed intermediate loop. The water-glycol is heated by seawater in plate heat exchangers. Water-Glycol as a secondary medium is suggested because of its thermodynamic properties with low freezing point, low cost and high availability. The heated water-glycol in-turn provides heat to the LNG, necessary for regasification of LNG into natural gas. There are two types of vaporisers commonly used in FSRU's as described below;

2.3.1 OPEN LOOP LNG VAPORISER

FSRU regasification system uses ambient seawater in open loop mode to convert LNG into natural gas. The seawater is used only as heating medium, with an intermediate closed water-glycol loop between seawater and LNG. The intermediate water-glycol loop significantly reduces the risk of freezing the seawater, as the seawater in this configuration, never exchanges heat directly with the cryogenic temperature of the LNG. Furthermore the use of glycol as intermediate heating medium instead of direct seawater heating enables the use of better suited LNG vaporizers both in terms of availability, maintainability and heat transfer area efficiency (printed circuit heat exchangers instead of titanium shell and tube heat exchangers).

2.3.2 CLOSED LOOP LNG VAPORISER

In closed loop system, FSRU boilers are used to heat the fresh water, which is then circulated through the shell-and-tube vaporizers in the regasification plant. This results in minimal usage of seawater by the FSRU.

Gas Metering System

Ultrasonic gas metering system will be provided for Gas Fiscal Metering.

Gas Export System

Gas shall be exported from the regasification plant through a high pressure gas pipe to a dedicated gas export manifold(s) on port side. The manifold(s) shall be equipped with ESD valves.

BOG Management

BOG management systems as described below will be installed on the FSRU. The BOG management system will be designed to recover BOG, hence minimizing operational cost and emissions.

Fuel for Dual Fuel Machinery

During all operating scenarios, BOG is the primary source of fuel for the Duel Fuel Diesel Engines (DFDE) machinery, which produces electricity for the FSRU operation. The DFDE engines may also operate continuously on Marine Diesel Oil (MDO). The amount of BOG used as fuel gas varies with the overall operating scenario of the FSRU.

Recondenser

During regasification operation, the excess BOG will be condensed back to liquid in the re-condenser system (capacity of re-condenser is depending on send out rate).

Gas Combustion Unit

A Gas Combustion Unit (GCU) will be installed on the FSRU, with capacity sufficient to deal with all excess BOG generated at maximum designed boil off rate with engines stopped (as per standard LNG carrier design requirements).

Utilities

The FSRU shall be self-sufficient with all utility systems required for the intended service. These will include:

– Instrument air
– Hydraulic system
– Electric power

In addition a seawater system (for open loop) or freshwater circulation system (for closed loop) shall be built in the fwd part of the FSRU, for supply of heating to the intermediate water glycol loops. For open loop designed, the sea water requirement at normal regasification capacity is 15000 m^3/hr; assuming 10^0C on the seawater inlet and a temperature drop of maximum 7^0C over the heat exchangers in the water glycol loops. A hypochlorite system and filters will be added to prevent marine growth and clogging of the sea water system.

Safety and Automation Systems

The FSRU will meet the technical safety requirements from the Classification Society. In addition to the prescriptive requirements in regulations, a risk based safety assessment will be carried out through several safety studies to ensure that the FSRU meets the risk acceptance criteria in the applicable regulations. The following is a summary of the main safety features related to the shutdown of the FSRU, demonstrating that the FSRU is able to shut down and sail away at short notice.

The fire precaution, extinguishing and firefighting apparatus will be provided in compliance with the requirement of SOLAS, Classification Society, and IMO Gas Carrier Code.

The emergency shutdown (ESD) system will be provided in compliance with the IGC code and Classification Society requirements.

Emergency Gas Relief System

Vent masts to be installed to ensure quick relief of the cargo tank pressure, in case of exceeding high pressure. Additionally, a high pressure emergency gas relief vent mast will be installed to ensure quick relief of the high pressure gas downstream the regasification plant in cases of emergency.

Emissions to water

The FSRU may be fitted with an open loop regasification system, where seawater will be used to vaporise and heat the LNG. An intermediate loop of water/glycol will be used; where the seawater heats the water/glycol; which in turn vaporises and heats the LNG. The regasification system can be designed such that the seawater will be cooled a maximum of 7^0C at peak regasification capacity and with a seawater inlet temperature of 10^0C.

Alternatively if a closed loop vaporiser system is utilised, discharges to water are reduced to a smaller amount of engine cooling water which will be discharged at a maximum of 6^0C above ambient sea water temperature.

Emissions to air

During normal operations the FSRU will use the boil off gas as fuel to the engines. The DFDE engines require a small amount of pilot fuel when operated in gas mode. During normal operations the DFDE economizer will produce enough heat/steam for heating purposes, but there might be a requirement to use the boiler in cases where the engine load is very low.

Waste to Shore

The following discharges to be collected and transported to shore for disposal:

- Contaminated slops water
- Solid waste
- Waste oils and lubricants

Flaring

The FSRU will be fitted with a cold vent used for emergency only. There will be no flaring on the FSRU.

Emergency Shut Down Systems

The FSRU shall have an Emergency Shutdown System according to Class rules, to isolate the High Pressure Gas systems and LNG Carrier in case of an emergency situation. Quick release mooring hooks shall be installed on the FSRU.

The ESD system will be designed to provide:

- A safe automatic shut-down of the equipment or machinery, upon detection of a potentially dangerous abnormal condition
- A control system for depressurization operations
- An interlock system to protect valuable equipment during all operation phases

The ESD will have the ability to continue operation, without upsets, even in case of one critical equipment failure.

Process Safety

The FSRU will be designed according the rules for regasification vessels for process safety. HAZOP will be conducted on the regasification unit and associated systems to ensure that all process upset conditions are uncovered and handled systematically.

Fire and Gas Leak Detection

The FSRU shall be fitted with a fire and gas detection and suppression system according to class requirements and industry standard. This will include a continuous gas detection system and fire detection system covering the regasification area. The requirements of active and passive fire protection will be adjusted based on the scenarios determined in the fire and explosion risk analysis.

Cryogenic spill on deck

The deck will be protected from cryogenic spill by the use of drip trays. The entire regasification module will be placed above a stainless steel tray to prevent any cryogenic leak hitting the vessel's deck. To remove hydrocarbons from the area after a spill, an overboard drain is fitted to the spill tray. By removal of hydrocarbons from the area, the likelihood and consequences of a pool fire is significantly reduced.

The LNG releases will be routed back to the cargo tanks instead of the vent mast whenever possible.

Onshore Utility Requirements

The FSRU is self-supplied with power generation capacity to handle all operating scenarios. Therefore, no shore power will be required. The FSRU is also capable of producing its own potable water.

The FSRU will require the following onshore services:

- Waste management facility,
- Bilge water handling,
- Bunkering facility,
- Provision of spares and stores, and
- Tug services.

To meet EIA requirements and access the impact of the Phase -1 facilities on environment the following studies were carried out

- Tranquillity and Mathematical Model study
- Mooring analysis for FSRU
- Cold Water Dispersion Study
- Risk analysis for FSRU
- Navigation simulation study for berthing against the FSRU
- Detailed Project Report (DPR)
- EIA study report incorporating additional impacts from FSRU

2.4 JETTY AND TERMINAL FACILITIES

The process facilities on the jetty for Phase - 1 will be minimal. The intention is that the FSRU will be equipped with all the facilities required by IMO, SIGTTO, OCIMF and relevant Classification for safe operation. The FSRU will be essentially independent of the shore based facilities. This includes all safety systems and fire fighting facilities.

Jetty shall broadly include - the jetty access trestle, access roads within port premises, mooring and breasting dolphins and associated marine systems such as quick release hooks, vessel handling related shore to ship communications, speed of approach radar and tugs. The marine facilities installed on jetty shall be suitable for Phase - 1 as well as for Phase - 2 operations.

Major item under Topsides would be two 100% capacity high pressure gas unloading arms, which will be installed on one of the Breasting Dolphins on the Jetty and will provide 100% redundancy to ensure the requisite reliability. The jetty control room will be constructed on the expansion loop of approach trestle; this building will be utilized in Phase - 1 and Phase - 2 operations. The building will also house electrical distribution panels to supply all the jetty based requirements including QRMH, Berthing Aid Systems, Unloading arms, lighting etc.

Fire fighting facilities on the jetty will conform to OISD 156. The facilities include 2 x 100% or 3 x 50% diesel Engine driven fire water pumps and two electric motor driven jockey pumps. The pumps will be located on an extension of the jetty trestle and will use sea water as fire water. Two water tower monitors and water curtain spray nozzles will be installed on the jetty head and Breasting Dolphin 1 respectively. Additional fire fighting facilities will include portable fire extinguishers, International Ship-Shore Connection, and hydrants and hose boxes. The fire water mains will be cement lined or poly glass lined carbon steel, or other material suitable for sea water service.

The Jetty control room building will be equipped with a Clean Agent fire suppression system as required.

Onshore Facilities

A 30” gas pipeline will be installed on the jetty which will run to the onshore terminal area where gas meters and pig launcher for the Jaigarh to Dabhol pipeline will be installed.

The facilities will be designed to minimize or eliminate discharges to atmosphere and hence a flare system is not required. Emergency relief valves will be discharged directly to atmosphere at a safe location, or if necessary connected to a cold vent stack in accordance with OISD standards.

Electric power will be generated on site by gas engine driven generators (2 x 200 kVA machines will be installed). The generators will be connected to a small substation/switchgear room.

A single diesel driven emergency power generator (approximately capacity 350 KVA) with fuel day tank of 990 litres capacity will be provided.

Power will be supplied to all the onshore facilities and also to the Jetty Control Room to supply all the Jetty power requirements.

An instrument equipment room combined with control room will be provided onshore. This room will house the control systems, SCADA, radio equipment and will be provided with operator interface console for the pipeline and terminal facilities.

Other buildings will include a combined workshop/ warehouse / administration building and medical treatment room.

Fire fighting facilities will consist of a Clean Agent - Dry chemical powder and CO_2 type fire portable extinguishers in accordance with OISD 226 requirements.

The location of the pipeline terminal and the onshore Early Production Facilities will be selected so as not to interfere with the construction of the Phase 2 facilities.

The gas pipe from the jetty will be routed along the North boundary of the onshore terminal plot, again to minimize potential interference with construction of Phase - 2.

Refer Annexure - II The plot area secured for the Phase - 1.

2.5 JAIGARH TO DABHOL TIE-IN PIPELINE

The re-gasified LNG will be delivered to GAIL's Gas trunk pipeline (at Dabhol) through an approx. 60 km, 30" cross country Pipeline which will act as Tie-In Line for further distribution to potential gas consumers.

The Tie-in connectivity was authorized by the Petroleum and Natural Gas Regulatory Board (PNGRB) vide letter no. Infra/PL/TIC-JD/H-Energy/01/15 dated 18th May, 2015.

The pipeline will be approximately approx. 60 Km in length and 30" OD and designed for a capacity of 6 MMTPA with provision of tap-off points at each of the SV stations for future connections. The pipeline will be designed fully in conformance with PNGRB Regulations, OISD 226 and ANSI B31.8.

The pipeline will be protected by external coating and cathodic protection system.

Electric power for the Sectionalising Valves Stations and the Dabhol terminal will be by Solar Powers. Backup power supply will be provided by connection to the State Grid.

A dedicated communication system Fibre Optic Cable/ satellite based will be provided. Master control stations will be located in the Jaigarh control room, and duplicated at a control room in HEGPL head office in Mumbai. A station repeater room will be provided at Dabhol terminal and at the three Sectionalising Valve Stations.

A pipeline terminal will be constructed at Dabhol, adjacent to the GAIL Dabhol pipeline terminal. The terminal will include pig receiver, 2 x 100% dust filters, and metering skids for custody transfer and flow/pressure control valves which will meter and regulate the flow to each of the GAIL pipelines.

The pipeline will be buried with a minimum cover of 1m and in case of Major River crossing the minimum cover will be 2.5 m below the scour level.

The pipeline will have broadly the following facilities:

a. Dispatch Station at Jaigarh
b. Three (3) SV Stations
c. Receipt Station at Dabhol
d. Dedicated communication system
e. Control station at Jaigarh
f. Remote operation of the pipeline
g. Cathodic Protection system
h. Leak detection System

At Dabhol, the pipeline will be connected to the following GAIL trunk pipelines:

1. Dahej-Uran-Panvel-Dabhol-Gas pipeline / Dabhol-Panvel Pipeline (DUPL / DPPL)
2. Dabhol-Bangalore Natural Gas Pipeline (DBPL)

The location of HEGPL terminal and the trunk pipelines are depicted in the map below:

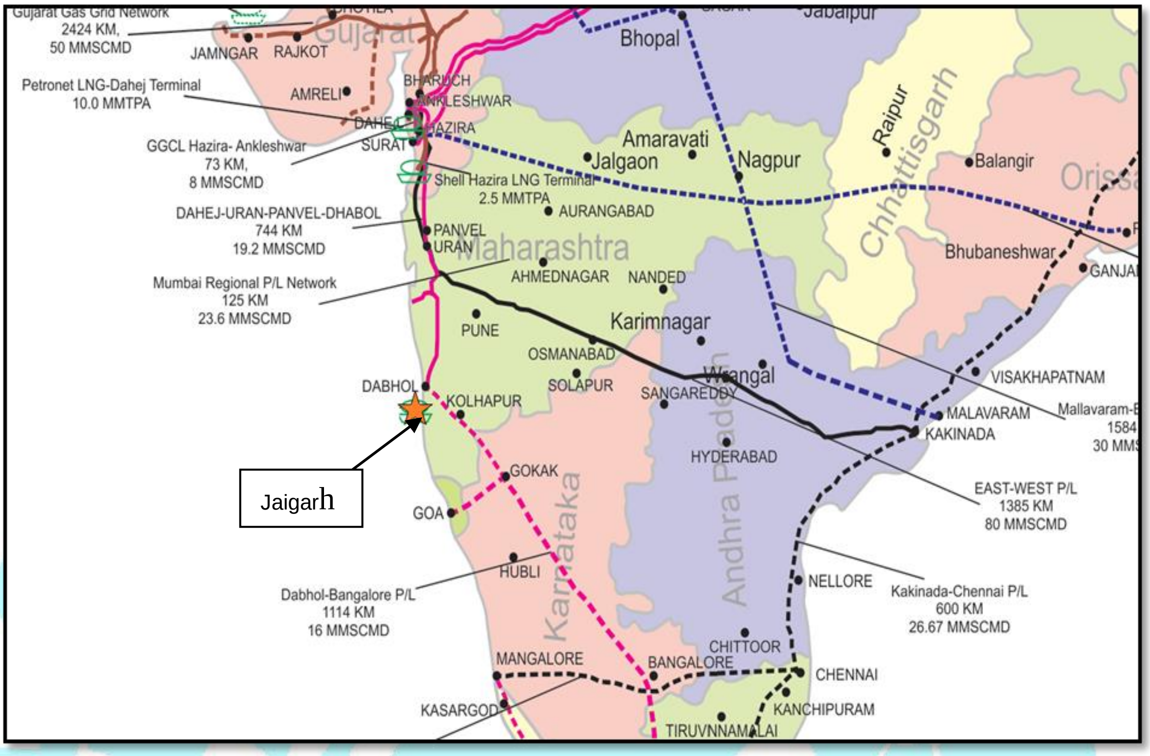


Figure 2.7: Pipeline Route Map

3 JAIGARH BELT

The coastal water of Jaigarh and the estuary does not receive any effluent from point sources. There are luxuriant mangroves growing along the Shastri estuary. The port is an active fish landing centre at this transect and has bauxite export from the port at Lavgaon and some industries are being set up around Jaigarh Port in recent years.

There are two monuments of historical and religious importance within the core area viz. Temple of Karteshwara and the Jaigarh Fort. The temple of Karteshwara or Shiva is located about 2 km south west of the proposed site on the slopes near the sea shore. Many devotees from all over Ratnagiri district visit this temple. The Jaigarh Fort is located about 2 km from the site. The Fort was built in 16th century by Shivaji as a naval base. Currently, the Fort is lying in state of neglect, with only a few tourists visiting it. At present the Fort is more often used to host various socio cultural activities of the nearby village.

JSW Jaigarh Port Ltd. is a subsidiary of Jindal South West group of companies and is governed by a board of Directors. Port is operational in Dhamankul Bay Jaigarh. The port is being developed as a deep sea water port, which will be catering to Panamax vessels of 60,000 to 70,000 DWT initially and Cape size vessels in the second phase. Jaigarh is connected by road with Ratnagiri town which is well connected to rest of the country by road and rail. The port will be functioning as a captive port for import of coal for sister concern, “JSW Energy” a thermal power station situated adjacent to the port itself.

The port is situated at about 60 km. North of Ratnagiri town. The Regional Port officer Ratnagiri is the supervisory authority from the Maharashtra Maritime Board. The port has been allotted sea front area along with required land to operate.

It is also important to note that this area receives good amount of rainfall (3500 mm) during SW monsoon period and cyclones passing through or from nearby areas are quiet common. In other words the monsoon is quite effective and vigorous in this region of Raigad district in north and Sindhudurg dist. in the south. In this backdrop the JSW Port assumes importance being strategically located and in private sector. All other minor / major ports are in Public sector. (Other private sector ports are having single captive jetties for their individual requirement).

4 DESCRIPTION OF MARINE ENVIRONMENT

The proposed project is located at JSW Jaigarh Port on the west coast of India in Maharashtra by entering in a sub-concession agreement with JSW Jaigarh Port Ltd (JSWJPL). The JSWJPL is situated on the mouth region of Shastri Estuary in Dhamankul Bay. The study area for field studies was therefore spread over the estuarine reach of Shastri Estuary and the coastal sea (Figure 4.0.1).

4.1 SHASTRI ESTUARY

The Shastri River, also known as the Shastri Jaygad River, is located on the northern side of Velneshwar. Covering a stretch of around 14.4 km in Velneshwar, the river passes through many villages including Jaigarh, Boria, Palshet and Malgund. Like the other coastal rivers of Maharashtra, it offers beautiful views of the village.

River Shastri is one of the few undammed, unpolluted and near pristine rivers in the Northern Western Ghats. The river emerges from Prachitgad, a historical fort in the newly-declared Sahyadri Forest Reserve at an elevation of 839 m above sea level and flows down to the west of the Sahyadri mountain ranges, meeting the Arabian Sea in a short journey of 90 km, forming a basin of 2173.55 km^2. The basin falls entirely in the Ratnagiri district, a region famed for its rich horticulture: Alphonso mangoes, cashew nuts and jackfruits. It covers three blocks: Sangameshwar, Ratnagiri and Guhagar. Tributaries of Shastri include Gadgadi, Bav, Gad, Asavi and Gandagi. In its short journey, Shastri provides goods and services to around 80 villages in the basin. It meets the sea near Jaigarh, forming a magnificent creek which is a haven for fishermen and mangroves and a rearing ground for fish and aquatic animals.

One Power plant has become fully operative from 2008 and a port is operating from 2009. These include Jindal group’s 1200 MW Coal based thermal power plant and M/s JSW Jaigarh Port Ltd., a constituent company of Jindal Group which is expected to handle 20 million tonnes cargo every year.

4.2 MARINE ENVIRONMENT

The Konkan coast is characterised by pocket beaches flanked by rocky cliffs of Deccan basalt, estuaries and patches of mangroves. The coast is a narrow stretch with an average width about 30-50 km composed of strips of plain between the sea and the hilly terrain of the Western Ghats or Sahyadris which runs parallel to the sea coast. The Konkan coast is an important sector on the west coast, because of its physical distinctiveness, biota and marine resources. The adjoining available continental shelf area of 1.12 x 10^5 km^2 is being extensively used for exploiting living and non-living resources like fishes, oil and gas.

4.3 FIELD INVESTIGATION

Field studies were carried out at 10 locations covering 12 km off the JSWJPL and Shastri Estuary marked on the Google map in Figure 4.0.1. A map showing the land use and land cover of the study area is given in Figure 4.3.1.

Subtidal sampling for water quality, sediment and flora and fauna was done over the estuarine stretch of about 9 km between JSW port and station 6. Stations 4, 5 and 6 were in the Shastri Estuary and stations 9 and 10 were sampled in the proposed FSRU location. Stations 1 to 3 and 8 represent near coastal region, whereas the station 7 represents offshore region. The geographical coordinates of the subtidal sampling locations are given in Table 4.3A.

Table 4.3: Coordinates of subtidal sampling locations

Station	Latitude	Longitude
J1	17°18’56.70”N	73°08’13.80”E
J2	17°18’59.90”N	73°09’43.30”E
J3	17°18’58.60”N	73°11’16.20”E
J4	17°17’27.20”N	73°13’29.80”E
J5	17°17’20.04”N	73°14’05.76”E
J6	17°17’17.63”N	73°16’20.40”E
J7	17°18’01.18”N	73°05’43.77”E
J8	17°17’56.51”N	73°09’37.69”E
J9	17°18’37.74”N	73°11’47.22”E
J10	17°18'54.10"N	73°12'23.80"E

Since the project site is surrounded by cliff, reclamation and jetties, appropriate intertidal exposure is not available. Hence, no intertidal sampling was possible.

4.3.1 PERIOD OF STUDY

Sampling was carried out during March 2017 (premonsoon season).

4.3.2 WATER QUALITY

4.3.2.1 SAMPLING PROCEDURE

Surface water for general analyses was collected using a polythene bucket while an adequately weighted Niskin sampler (Plate 1) with a closing mechanism at a desired depth was used for obtaining subsurface water samples. Sampling at the surface and bottom (1m above the bed) was done when the station depth exceeded 3 m. For shallow regions only surface samples were collected.

4.3.2.2 METHODS OF ANALYSIS

Majority of water quality parameters was analysed in the field laboratory temporarily established in the township of JSW Jaigarh Port, Jiagarh. Colorimetric measurements were made on a UV 1240 (Shimadzu) Spectrophotometer (Grasshoff 1983). RF-5301 Shimadzu Spectrofluorometer was used for estimating PHc. The analytical methods of estimations were as follows:

i) Temperature

Temperature was recorded using a calibrated mercury thermometer with an accuracy of 0.1°C.

ii) pH

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

iii) Suspended Solids

A known volume (500 ml) of water was filtered through a pre-weighted 0.45 um Millipore membrane filter paper, dried and weighed again. The difference in weight gave value of suspended solid.

iv) Salinity

Salinity was measured using AUTOSAL salinometer (GUILDLINE Instruments Ltd., Canada). The instrument was standardised with IAPSO standard sea water (OSIL, UK).

v) DO and BOD

DO was determined by Winkler method. For the determination of BOD, direct un-seeded method was employed. The sample was filled in a BOD bottle in the field and was incubated in the laboratory for 3 days after which DO was again determined (Grasshoff 1983).

vi) Phosphate

Acidified molybdate reagent was added to the sample (25 ml) to yield a phosphomolybdate complex, which was then reduced with ascorbic acid to a high 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 reached with N-(1-napthyl)-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 described earlier 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 hypocholorite to obtain blue colour of indophenol. The absorbance was measured at 630 nm.

x) Total phosphorus

Phosphorus compounds in the sample were oxidised to phosphate with alkaline potassium persulphate at high temperature and pressure. The resulting phosphate was analyzed as described under (vi).

xi) Total nitrogen

Nitrogen compounds in the sample were oxidised to nitrate with alkaline potassium persulphate at high temperature and pressure. The resulting nitrate was estimated as given under (viii).

xii) PHc

Water sample was extracted with hexane and the organic layer was separated, dried over anhydrous sodium sulphate and reduced under low pressure. Fluorescence of the extract was measured at 360 nm (excitation at 310 nm) with Saudi Arabian Crude residue (boiling point >100^o C) as a standard (IOC-UNESCO 1984).

xiii) Phenols

Phenol in water was 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.

4.3.3 SEDIMENT QUALITY

4.3.3.1 SAMPLING PROCEDURE

Surficial bed sediment from all locations was either handpicked from intertidal areas or obtained with a van Veen grab in sub-tidal areas (Plate 2). The sediment after retrieval was transferred to a polythene bag and preserved for further analysis at Mumbai.

4.3.3.2 METHODS OF ANALYSES

i) Metals

The dried and powdered sediment was brought into solution by treatment with concentrated HF-$HClO_4$-HNO_3-HCl acids and the metals aluminium, chromium, manganese, iron, cobalt, nickel, copper and zinc were estimated by dual view inductively coupled plasma emission optical emission spectrophotometer (ICP-OES, plasma 7300 DV, Perkin Elmer, Singapore), while lead and cadmium were analysed by graphite AAS on a Perkin Elmer Analyst 600 atomic absorption spectrophotometer (Loring D H and Rantala 1992)

For the estimation of Hg, the sample was treated with conc. HNO_3 and Hg after reduction was estimated by cold vapour AAS.

ii) Organic carbon

The C_{org} in sediment was determined by oxidizing the organic matter in the sample by chromic acid and estimating excess chromic acid by titrating against ferrous ammonium sulphate (Walkely, A and I.A Black 1934).

iii) Phosphorus

The sediment was brought into solution by treatment with concentrated HF-$HClO_4$-HNO_3 acids and phosphorus was estimated as described under Section 4.3.2.2 (vi).

iv) PHc

The sediment after refluxing with KOH-methanol mixture was extracted with hexane. After removal of excess hexane, the residue was subjected to a clean-up procedure on alumina column. The PHc content was then estimated by measuring the fluorescence as described in Section 4.3.2.2 (xii) with Saudi Arabian Crude residue as standard.

4.3.4 FLORA AND FAUNA

4.3.4.1 SAMPLING PROCEDURE

Water and sediments samples for microbiological analysis were collected in a sterilized BOD bottles and in sampling bag/polycarbonate bottle respectively. Hands and polyethylene bucket were cleaned by detergent and clean water, then surface sterilized by 70% isopropanol. Sample was collected in bucket and then collected in sterile BOD bottles with appropriate label.

Sediment samples were collected by using a van-Veen Grab with proper precaution and the subsample was transferred to sterile sampling bag or sterile polycarbonate bottle with lids. All microbiology samples were immediately stored in ice box and transported to microbiology lab within two hours.

Polyethylene bucket and Niskin sampler were used for sampling surface and bottom waters respectively 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 haul using a Heron Tranter net (mesh size 0.20 mm, mouth area) with an attached calibrated flow meter. 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. The sediment was sieved through a 0.5 mm mesh sieve and animals retained were preserved in 5% buffered formaldehyde Rose Bengal.

4.3.4.2 METHODS OF ANALYSES

i) Microbes

Samples were analyzed by serial dilution followed by spread plate techniques for Total Viable Counts (TVC), Total Coliform (TC), *Escherichia coli* like organisms (ECLO), Faecal coliform like organisms (FC), *Shigella* like organisms (SHLO), *Salmonella* like organisms (SLO), *Proteus / Klebsiella* like organisms (PKLO), *Vibrio* like organism (VLO), *Vibrio parahaemolyticus* like organisms (VPLO), *Vibrio cholerae* like organism (VCLO), *Pseudomonas aeruginosa* like organism (PALO) and *Streptococcus faecalis* like organisms (SFLO). Colonies of TC, ECLO, VLO and VPLO were counted separately. The media employed for growth of bacteria were as follows:

Nutrient agar (NA) for TVC, MacConkey agar(MC) for TC, M7HrFC agar for ECLO, MFC agar for faecal coliform, Xylose-lysine Deoxycholate agar (XLD) for SHLO, SLO and PKLO, Thiosulphate citrate bile salts sucrose medium (TCBS) for VLO, VPLO and VCLO, Centrimide agar (CS) for PALO and M-Enterococcus agar for SFLO.

ii) Phytoplankton pigments

A known volume of water (500 ml) was filtered through a 0.45 µm Millipore membrane filter paper and the pigments retained on the filter paper were extracted in 90% acetone. For the estimation of chlorophyll *a* and phaeophytin the fluorescence of the acetone extract was measured using Fluorometer (Turner Design) before and after treatment with dilute acid (0.1N HCl).

iii) 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.

iv) Mangroves

Presence of mangroves, if any in the area were assessed during study period.

v) 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.

vi) Benthos

(a) **Macrobenthos**: The sediment was sieved through a 0.5 mm mesh sieve and animals retained were stained with the Rose Bengal and preserved in 5% buffered formaldehyde. Total population was estimated as number of animals in 1 m^2 area and biomass on wet weight basis (g/m^2).

(b) **Meiobenthos:** Total population was estimated as number of animals in 10 cm^2 area and biomass on wet weight as $\mu g/10cm^2$ basis.

vii) Photographs

Photographs taken during field studies are reproduced in relevant section.

4.4 ASSESSMENT OF WATER QUALITY

4.4.1 TEMPERATURE

Results of water quality are given in Tables 4.4.1.Water temperature generally regulates species distribution, their composition and activity of organisms associated with aquatic environment. Since most of the aquatic animals are cold blooded, water temperature regulates their metabolism and ability to survive and reproduce effectively. Hence artificially induced changes such as those by the return of warm water may alter indigenous ecosystems. An upper threshold limit of 35^{o} C is considered for tropical aquatic species though many may be less tolerant. For the ease of presentation of results, the study area was divided in different zones as follows:

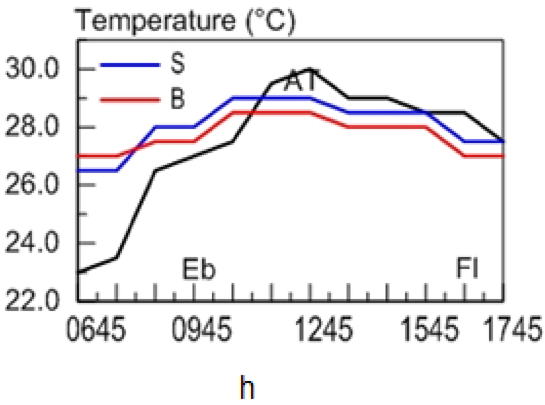
Zone	Station
Offshore	J7
Coastal	J1, J2, J3 & J8
FSRU site	J9 & J10
Lower estuary	J4 & J5
Upper estuary	J6

Water temperature in shallow zones is expected to vary in accordance with the air temperatures. During the present study also it varied in accordance with air temperature. Thus the air temperature varied in 23.0-30.0°C range and the water temperature was in the range of 26.5-29.5°C. Variations in temperature between the surface and the bottom were minor suggesting vertically well-mixed water mass.

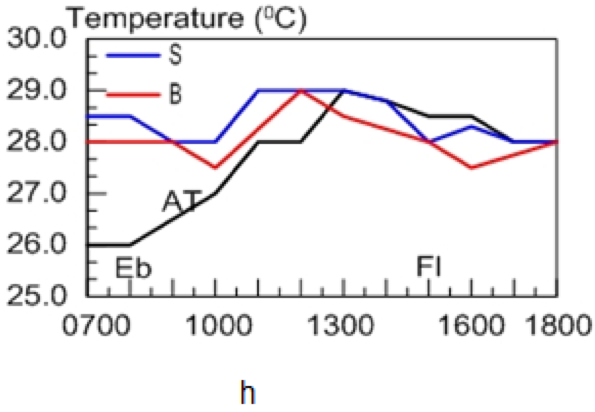
Average values of the water temperature recorded at different stations in the present study are given in the table below:

Station	Temperature(°C)
J1	27.3
J2	27.8
J3	28.0
J4	27.9
J5	27.3
J6	27.0
J7	28.8
J8	29.3
J9	28.1
J10	28.3

Temporal variation: Temporal variation of temperature recorded during March 2017 is given below:



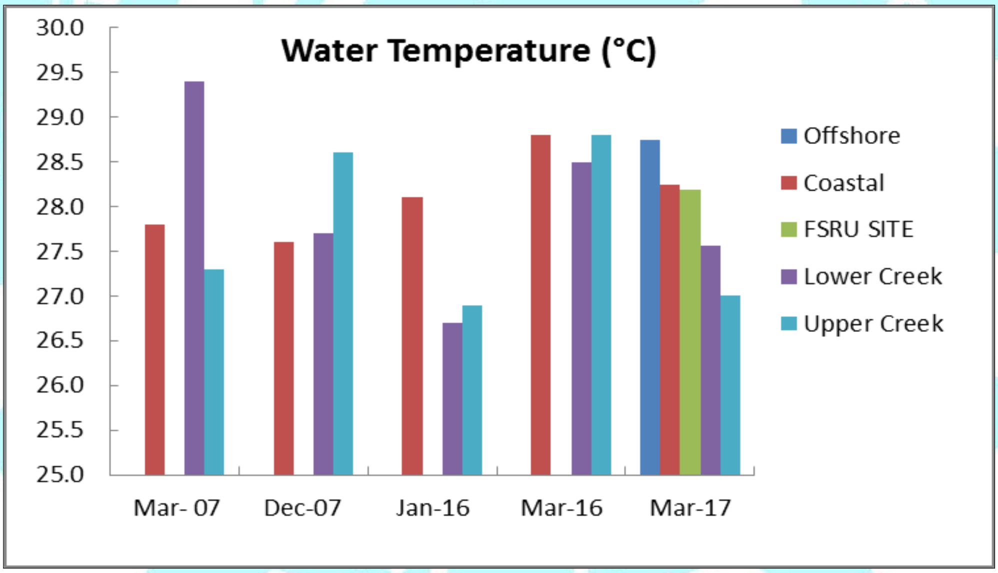
Station J4



Station J9

considerably, depending upon time of collection the water temperature was between 26.5 and 29.0°C at station J4 27.0 29.0°C at station J9. Difference in temperature from the surface to the bottom was minor, indicating a well mixed water body.

Long term average temperature (°C) recorded in the study region is presented graphically in the Figure below:



It is evident that the overall average value of water temperature recorded during different years and seasons varied widely, which could be attributed to time and the season of collection.

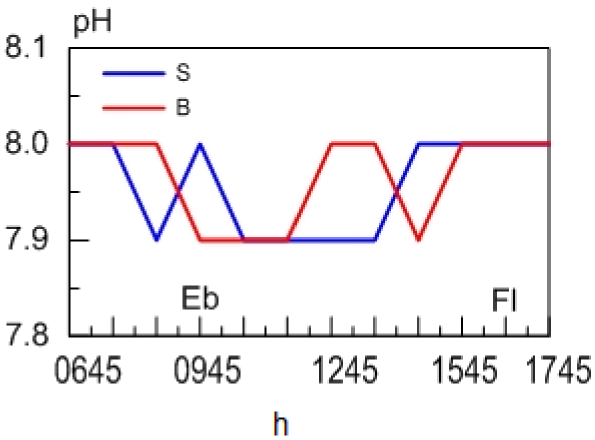
4.4.2 pH

The principal system that regulates pH of seawater is the carbonate system consisting of CO_2, H_2CO_3, HCO_3^- and CO_3^{2-}. Because of the buffering capacity of seawater, generally seawater pH has limited variability (7.8-8.3). In shallow, biologically active tropical waters, large diurnal pH changes – from 7.3 to 9.5, may occur naturally because of photosynthesis. In the nearshore and estuarine systems influx of freshwater, particularly during monsoon, can affect the buffering action and the pH often remains below 8.0. Though pH range of 5 to 9 is not directly harmful to the aquatic life, such changes can make many common pollutants more toxic. The average values of pH recorded at different stations are given below:

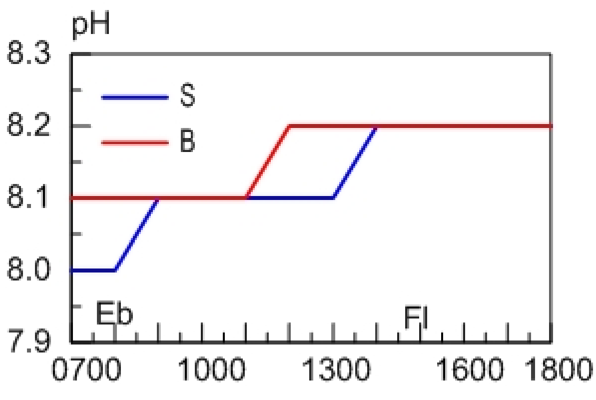
Station	pH
J1	8.2
J2	8.2
J3	8.2
J4	8.0
J5	8.0
J6	8.0
J7	8.2
J8	8.1
J9	8.1
J10	8.1

Thus the average pH of the study area was 8.0-8.2 during present study and was well within the range of seawater**.**

Temporal variation: Values of pH recorded temporally during March 2017 are presented in the graph below:



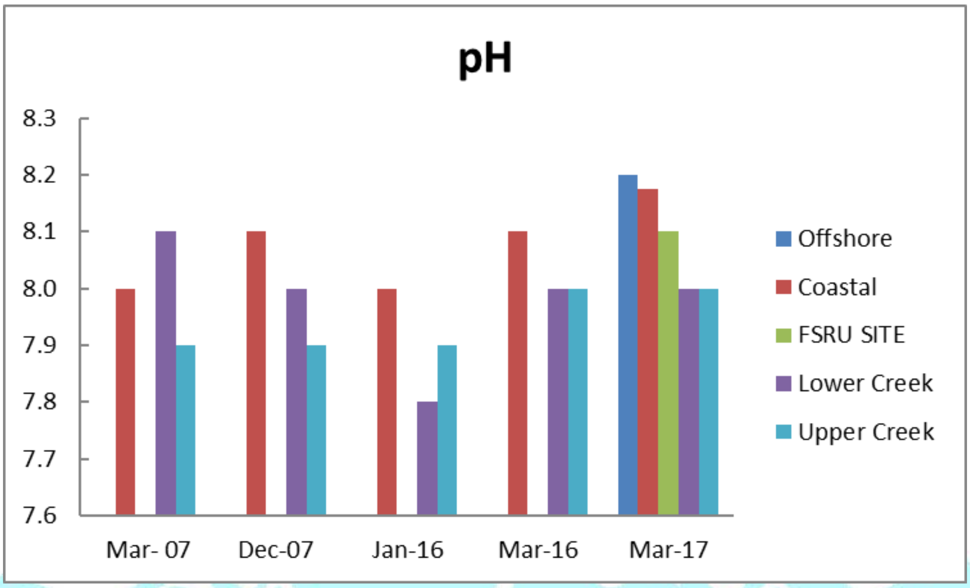
Station J4



Station J9

As evident from the above figures, pH varied in a very narrow range, though marginal increase of pH was recorded at high tide at station J9.

The long-term average variations in pH (2007-2017) are given in the Figure below:



The above figure indicates that the pH varied in a narrow range (7.8-8.2) during different periods of the study.

4.4.3 SUSPENDED SOLID (SS)

SS of natural origin mostly contains clay, silt and sand of bottom and shore sediments, and plankton. For estuaries and nearshore areas, clay and vegetation matter form important components of SS. Though substantial quantity of sediment is added through rain runoff, the major contribution in estuaries comes from the disturbance of bed and shore sediments; tidal currents being the vital influencing factor for SS typically leading to high values in the bottom water. Anthropogenic discharges also add a variety of SS depending upon the source.

High SS in the water column can negatively influence sensitive populations through mortality, reducing growth rate and resistance to diseases, preventing proper development of fish eggs and larvae, modifying natural movement and migration and reducing abundance of available food. Hence, biological diversity in zones of high turbidity is often lower than areas with low turbidity.

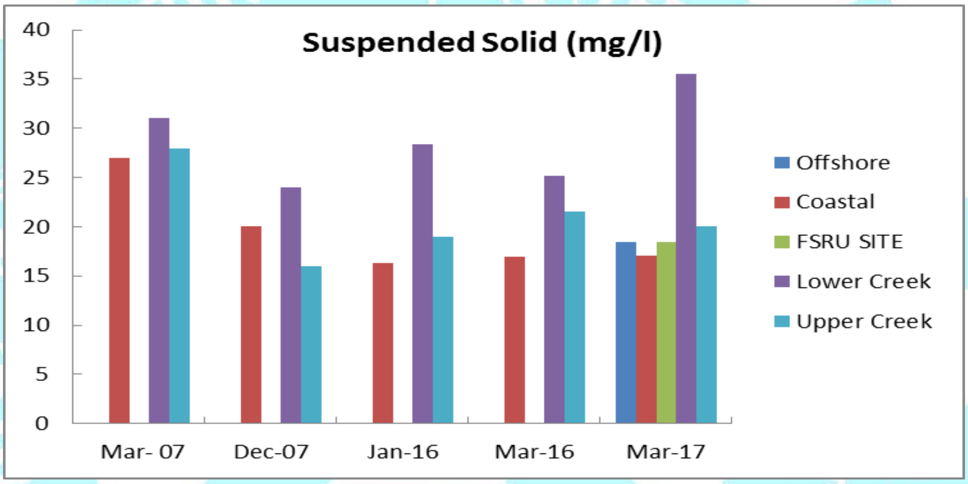
The average values of SS recorded at different stations during present study are given below:

Station	SS (mg/l)
J1	15
J2	17
J3	19
J4	48

J5	23
J6	20
J7	18
J8	17
J9	17
J10	19

The average concentration of SS was in the range 15 to 48 mg/l during the present study. SS in the Shastri Estuary was also low.

The long-term average variations in SS (mg/l) (2007-2017) are given in the Figure below:



It is evident from the above figure that average value recorded in lower estuary was always higher compared to other segments during different seasons. This may be due to disturbance by local activities such as vessel movements as the region is in the vicinity of the Jaigarh Port.

4.4.4 SALINITY

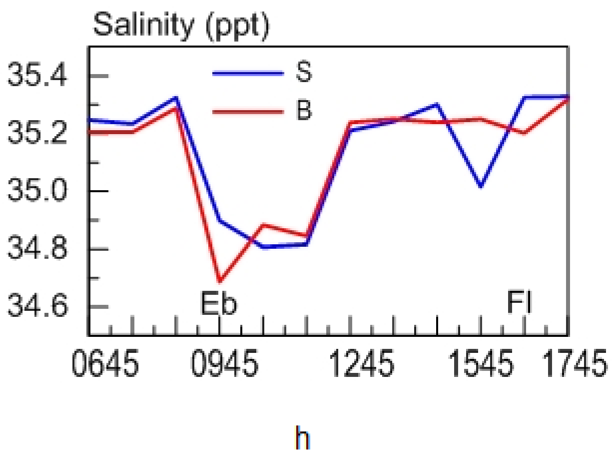
Salinity is an indicator of extent of freshwater inflow in tidal waters and estuaries in particular. Normally seawater salinity is 35.5 ppt which may vary depending on competition between evaporation and precipitation.

Flora and fauna inhabiting inshore and coastal waters are generally acclimatized to a certain range of salinity where they thrive. Evidently, wide changes in salinity, such as in monsoon, can result in adoption with modification and dominance of selected species in the lower order while higher order biota may migrate. Sudden changes in salinity may even cause mortality of organisms including fish due to salinity shock.The average salinity recorded during present study is given below:

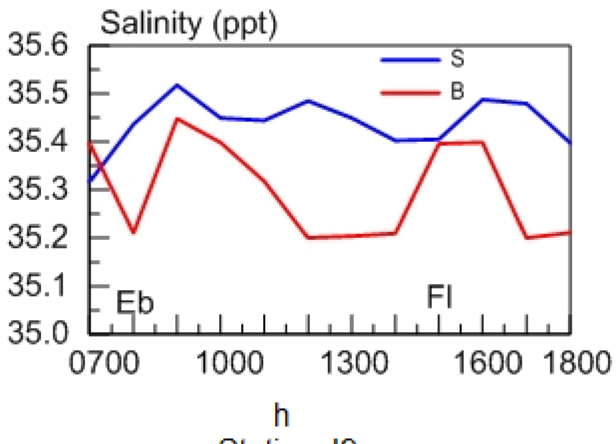
Station	Salinity (ppt)
J1	35.2
J2	35.3
J3	35.3
J4	35.1
J5	35.1
J6	34.5
J7	35.3
J8	35.2
J9	35.4
J10	35.3

It is evident from the above table that the salinity at all stations was in the range of the coastal seawater, where there is no influx of freshwater. However, salinity of upper estuarine zone of Shastri Estuary indicated influx of freshwater during ebb.

Temporal variation; StationsJ4 and J10 were studied for temporal variations and the results are presented as below:



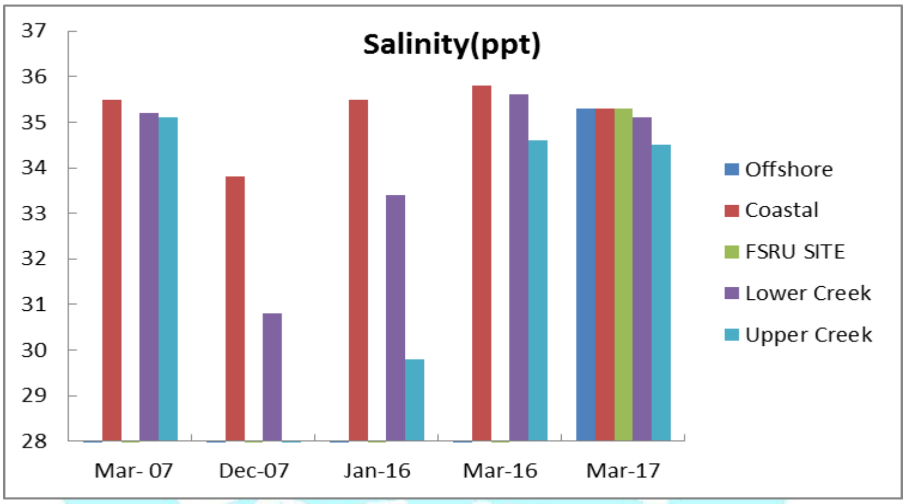
Station J4



Station J9

Thus the salinity decreased during ebb period at station J4, which is near the Jaigarh Port in the Shastri Estuary, indicating minor influence of freshwater. However, at station J10, which represents the FSRU site, the salinity variation was only 0.2 ppt, revealing the absence of freshwater influence at the site. There were no marked variations between surface and bottom salinity, which is expected for vertically well-mixed marine areas.

The long-term average variations in Salinity (ppt) (2007-2017) are given in the Figure below:



Thus salinity values recorded during these studies are in a narrow range. However, seasonal variations were seen during the results of post and pre-monsoon periods in the upper estuarine zone.

4.4.5 DO AND BOD

DO is an important parameter in water quality since it is an indicator of ability of a water body to support life. DO in a water body is a balance between replenished through photosynthesis and dissolution from the atmosphere and its removal through respiration. In unpolluted waters the rate of consumption of DO is lower than the rate of replenishment resulting in maintenance of adequate concentrations. Release of anthropogenic discharges containing organic matter such as sewage can consume DO more than that the water body can replenish creating under-saturation which, in extreme cases, may lead to onset of anoxic anoxic conditions with mal-odorous emissions thereby degrading the ecological quality.

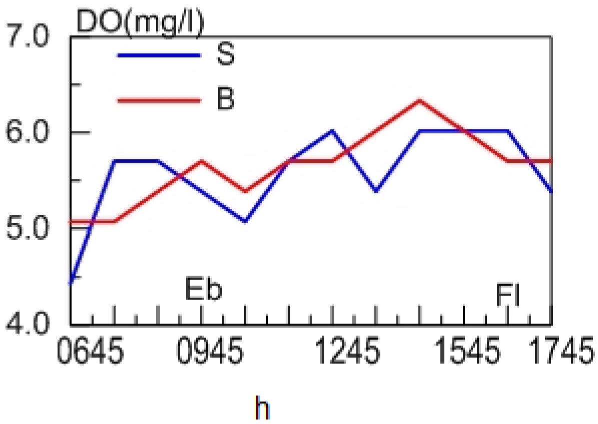
Below 2 mg/l concentration of DO, good and diversified aquatic life may not be maintained since feeding of many organisms is diminished or stopped and their growth is retarded at low DO levels. Embryonic and larval stages of aquatic life are especially vulnerable to reduced conditions and may also result in retarded development and even partial mortality. It is considered that the level of DO should not fall below 4 mg/l for prolonged periods and recommended minimum level for tropical marine fish is 4- 5 mg/l or 75 % saturation level.

Average values of DO (mg/l) at different stations during the present study are tabulated below:

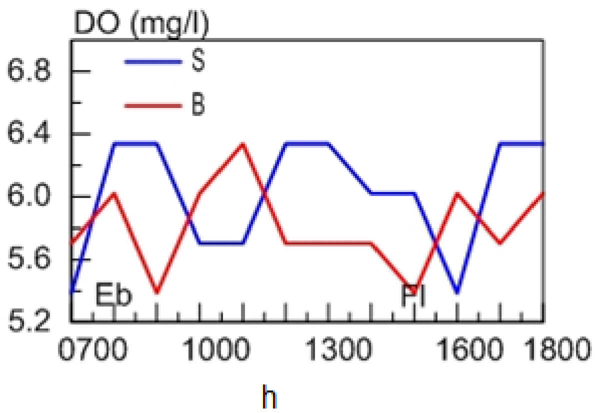
Station	DO (mg/l)
J1	6.2
J2	6.3
J3	6.0
J4	5.6
J5	6.3
J6	6.5
J7	6.1
J8	6.2
J9	5.9
J10	6.0

Thus, the DO concentration was in normoxic range (DO value 6.0 mg/l or above), indicating good oxidizing condition in the region.

Temporal variation: Temporal variation of DO is presented graphically below:

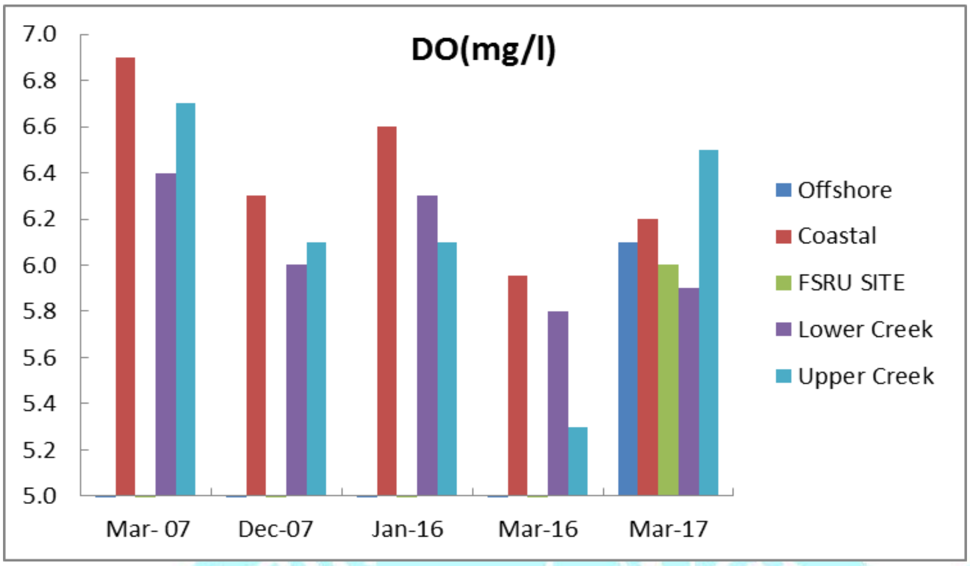


Station J4



Station J9

Thus there was no distinguished tidal trend in the variation of DO. The long-term average variations in DO (mg/l) (2007-2017) are given in the Figure below:



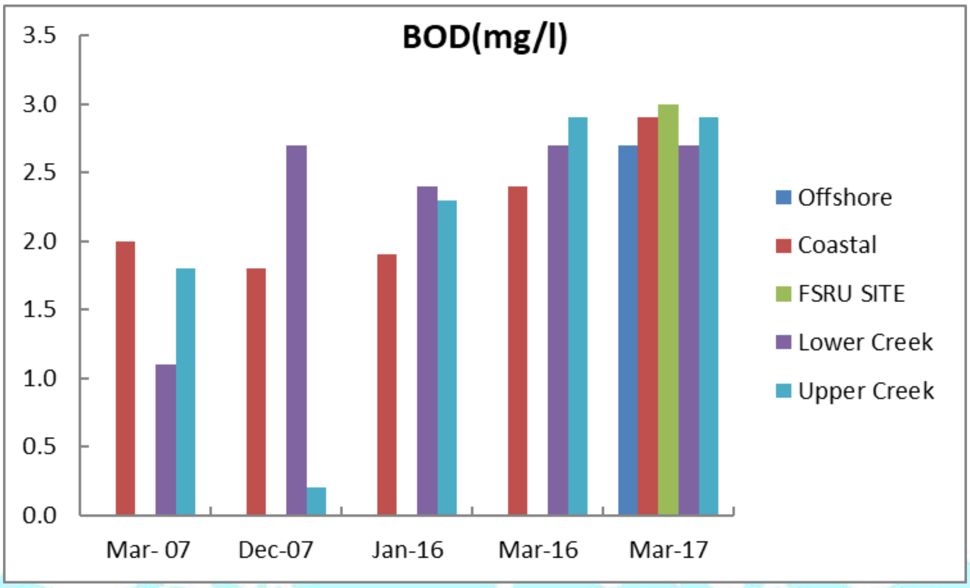
The above figure indicates good average DO content with good oxidizing condition and increased photosynthetic activity in the water of study area. The present study of Jaigarh sustains the normoxic condition and there is no deficiency of DO in the region and its values are comparable from earlier data.

Average values of BOD (mg/l) at different stations are given below:

Station	BOD (mg/l)
J1	2.9
J2	3.2
J3	3.3
J4	3.1
J5	3.5
J6	2.9
J7	2.7
J8	3.4
J9	2.8
J10	3.3

The average BOD values were between 2.7 and 3.5 mg/l during the present study. These values indicate the absence of gross anthropogenic organic load in the region

The long-term average variations in BOD (mg/l) (2007-2017) are given in the Figure below:



Though BOD values are in the range, generally recorded in the area free from any organic load, a marginal increase in the values occurred in recent years, which may be due to increased human activities in the region.

4.4.6 PHOSPHORUS COMPOUND

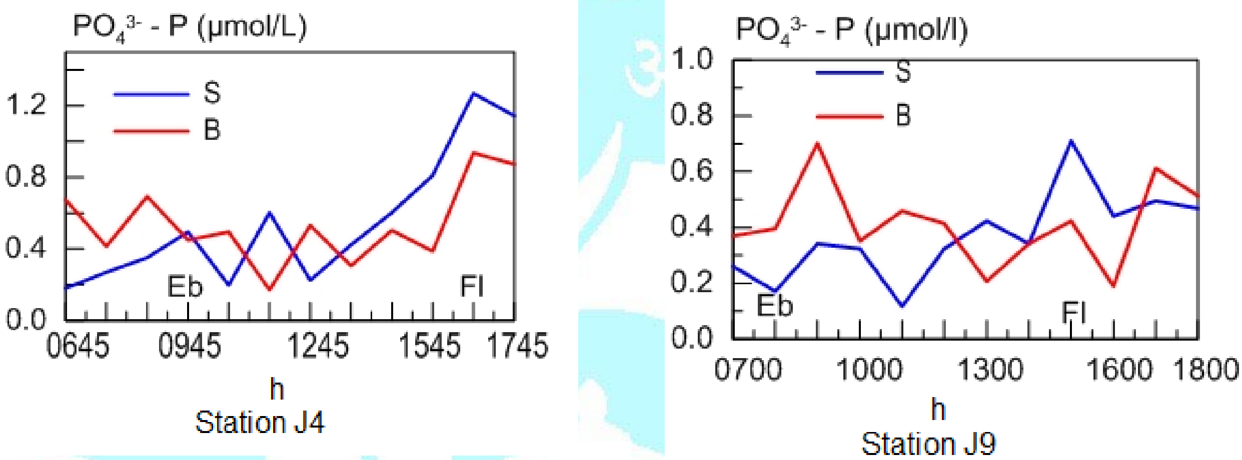
Phosphate (PO_4^{3-}-P) is one of the major nutrients required for plant nutrition and essential for life. However, their high concentrations can lead to excessive growth of algae which in extreme conditions results in eutrophication. Sources of phosphate in coastal marine environment include domestic sewage, detergents, effluents from agro-based and fertilizer industries, agricultural runoff, organic detritus such as leaves, cattle waste etc.

The average concentration of PO_4^{3-}-P (µmol/l) at different stations during present study are given below:

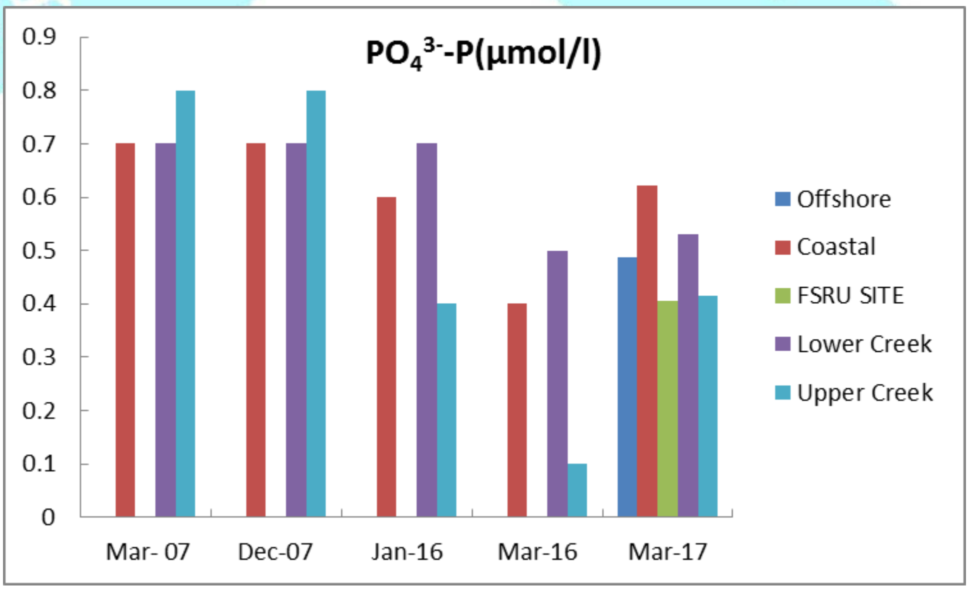
Station	PO_4^{3-}-P (µmol/l)
J1	0.5
J2	0.6
J3	0.6
J4	0.5
J5	0.5
J6	0.4
J7	0.5
J8	0.8
J9	0.4
J10	0.4

The average concentration of PO_4^{3-}-P varied in the range of 0.4-0.8 µmol/l during the present study. The average concentration indicates that the maximum concentration at station J8, which represents coastal water. However, minimum concentration was recorded at FSRU site. These concentrations can be considered as background values, as there is no significant source of pollution in the region.

Temporal variation: Temporal variation of PO_4^{3-}-P recorded at stations J4 and J9 are presented in the figure below:



From the above figure, it is evident that variation in concentration of PO_4^{3-}-P was random. However, an increase of PO_4^{3-}-P during flood at station J4 indicates some local perturbations. The values were < 1.4 µmol/l at station J4 and < 0.8 mol/ at station J9. The long-term average variations in PO_4^{3-}-P (µmol/l) (2007-2017) are given in the Figure below:



As evident from the above figure that there is no trend in the variation of PO_4^{3-}-P concentration but was below 1 µmol/l and varied randomly depending upon time and season of collection.

4.4.7. NITROGEN COMPOUNDS

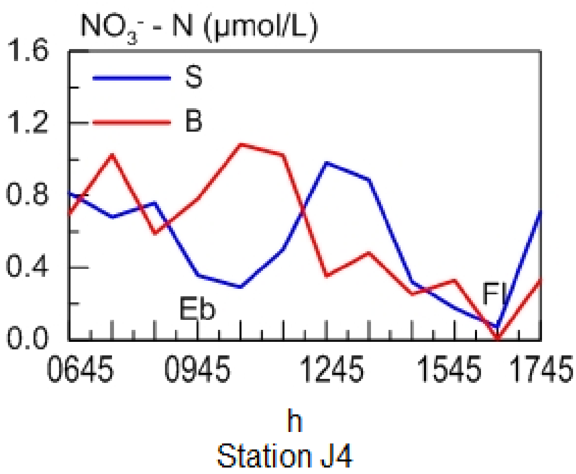
Nitrate, nitrite and ammonia are the major species of nitrogen of which nitrate is generally dominant. Nitrite is thermodynamically unstable and ammonia is biochemically oxidized to nitrate via nitrite apart from being directly assimilated by algae. Hence, concentrations of nitrite and ammonia are often very low in natural waters. In well-oxygenated coastal waters, nitrate-nitrogen is the dominant species of nitrogen.

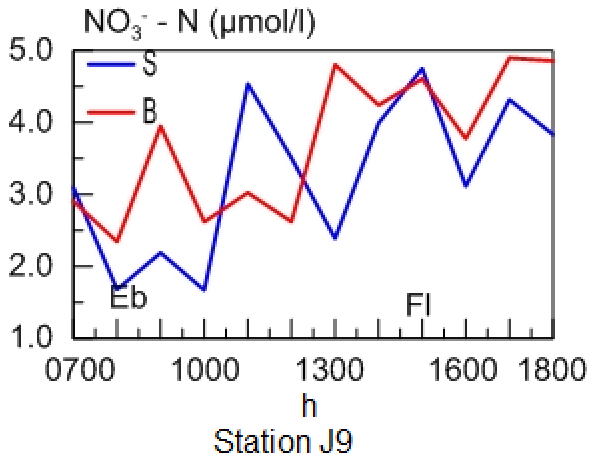
The average concentration of NO_3^--N recorded at different stations during the present study are given in the table below:

Station	NO_3^--N (µmol/l)
J1	0.4
J2	1.0
J3	4.0
J4	0.6
J5	0.7
J6	0.5
J7	17.6
J8	1.9
J9	3.5
J10	0.2

The average NO_3^--N concentration varied from 0.2 µmol/l to 17.6 µmol/l during March 2017 and the values were in the range generally observed in the nearshore uncontaminated coastal waters. The maximum average concentration of NO_3^--N was recorded at station J7, which is the offshore station. It could be a random value and natural occurrence – not uncommon in dynamic marine areas.

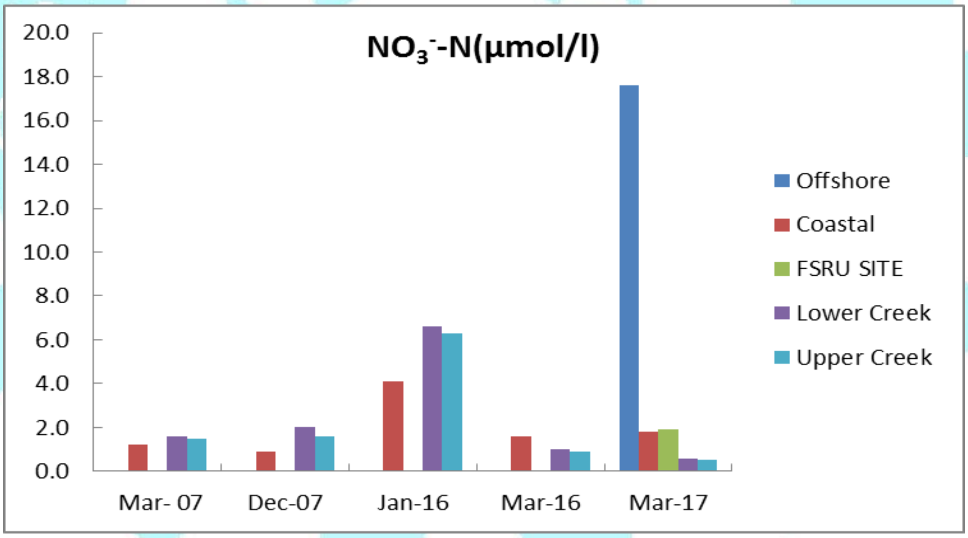
Temporal variations: Temporal variation of NO_3^--N recorded at stations J4 and J9 during March 2017 are presented in the figures below:





The above figures reveal that variation in concentration of NO3$^-$-N was random and no particular tide dependent changes were recorded at station J4, though lowest concentration was recorded during flood. At station J9 higher concentration was recorded in high tide, indicating local influence of openshore water, as NO_3^--N concentration was highest at the offshore station.

The long-term average variations in NO_3^--N (µmol/l) (2007-2017) are given in The Figure below:



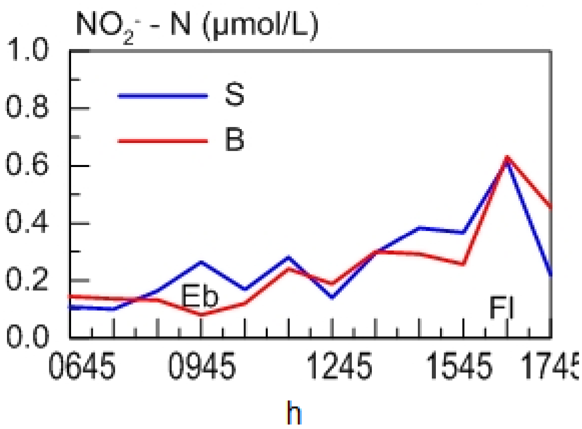
It is evident from the above figure that the variation in the concentration of NO_3^--N was random. The highest concentration was at offshore location. However, it cannot be compared with earlier data, as this station was sampled for the first time.

The concentration of NO_2^--N in natural coastal waters with good oxidizing conditions is generally below 2 µmol/l. Its average concentrations recorded at different stations during present study are given in the table below:

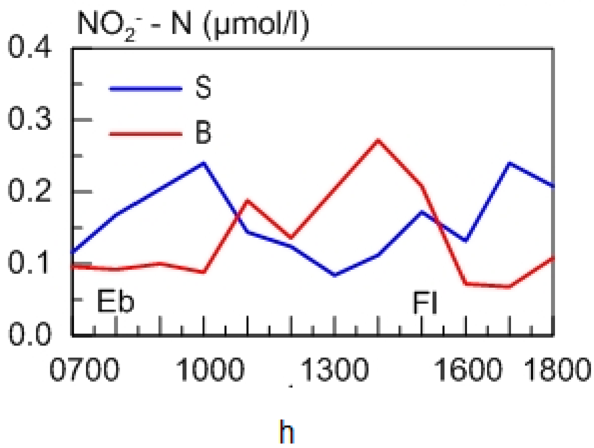
Station	NO_2^--N (µmol/l)
J1	0.1
J2	0.2
J3	0.2
J4	0.3
J5	0.2
J6	0.2
J7	N.D
J8	N.D
J9	0.1
J10	0.2

The average concentration of NO_2^--N varied from N.D to 0.3 µmol/l, with maximum concentration (0.3 µmol/l) at station J4. Hence, concentration of NO_2^--N was <0.6 µmol/l throughout the study region as expected in well-oxygenated waters.

Temporal variation: Temporal variation of NO_2^--N recorded at stations J4 and J9 are presented in the figure below:



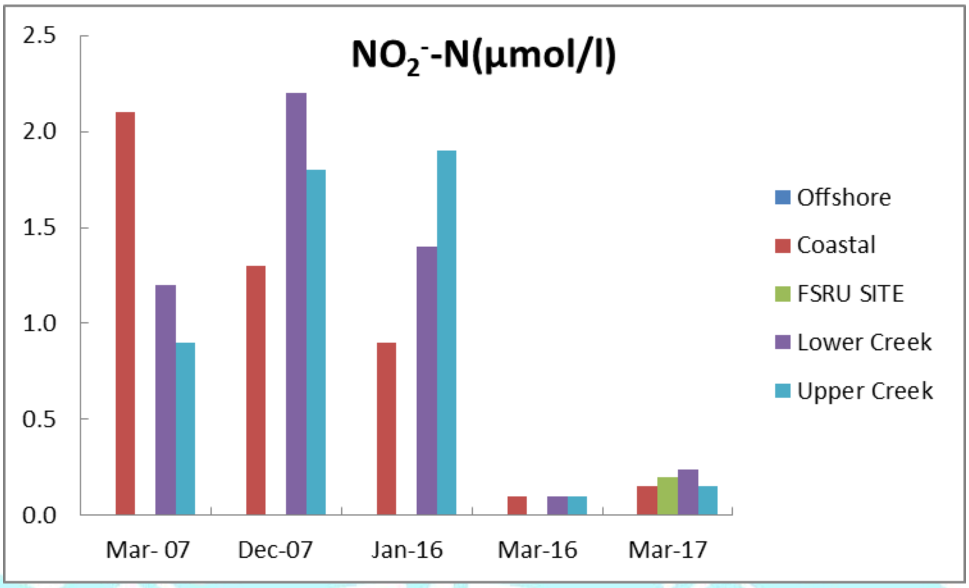
Station J4



Station J9

As evident from above figures, there is trend of increase of NO_2^--N during flood at station J4. However, no particular tidal trend in the concentration of NO_2^--N was recorded at station J9

The long-term average values of NO_2^--N (µmol/l) (2007-2017) are given in the Figure below:



The above figure indicates that values of NO_2^--N are lower in recent years compared to earlier studies. Nevertheless, the values were <2.5 µmol/l as expected.

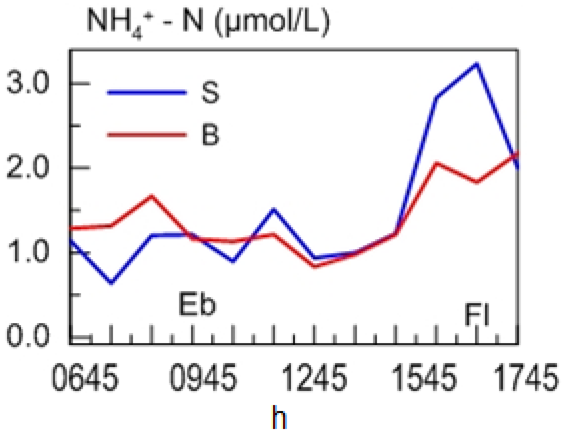
Similar to nitrite, ammonia is unstable in the oxygenated waters and is oxidized to nitrate via nitrite. The average concentrations of NH_4^+-N (µmol/l) in the study area varied as given in the following table:

Station	NH_4^+-N (µmol/l)
J1	1.4
J2	1.6
J3	1.6
J4	1.4
J5	1.0
J6	3.6
J7	1.8
J8	1.4
J9	1.6
J10	1.2

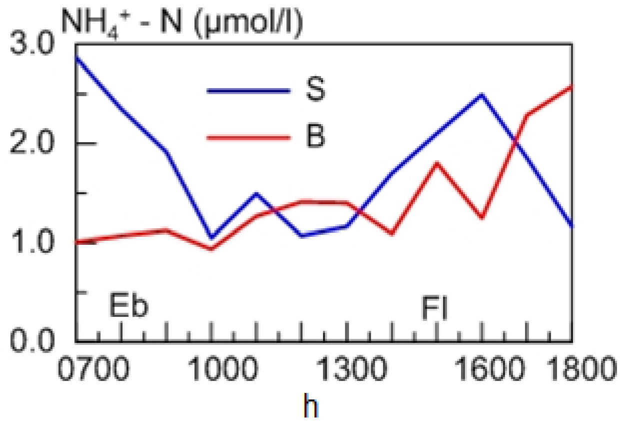
Marginally elevated value averaging at 3.6 µmol/l at station J6 suggests some anthropogenic influence.

Temporal variation:

Temporal variation of NH_4^+-N recorded at stations J4 and J9 are presented in the figure below:



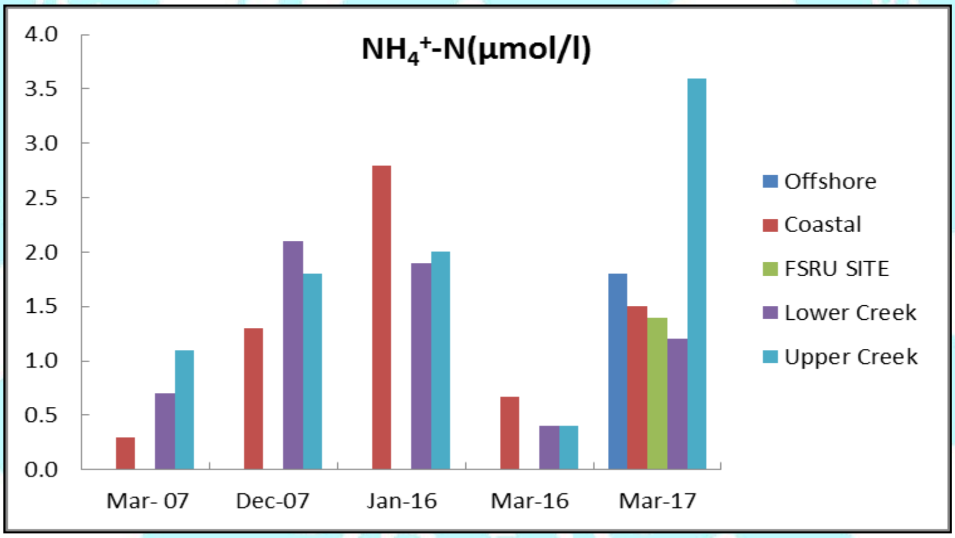
station J4



Station J9

It is evident from above figures that the concentration of NH_4^+-N was high at station J4 during flood. At station J9 also elevated concentration of NH_4^+-N was recorded prior to ebb period.

The long-term average variations in NH_4^+-N (µmol/l) (2007-2017) are given in the Figure below:



As it is evident from the above figure, the NH_4^+-N concentration was high in the Upper Creek during the present study. Except during March 2016, the concentration NH_4^+-N in the estuarine region seems to have increased with time, indicating increased input from land based sources.

4.4.8 PETROLEUM HYDROCARBONS (PHc)

Naturally occurring hydrocarbons in aquatic environment are in trace amounts of simple forms produced by microbes. PHc derived from crude oil and its products are added to marine environment by anthropogenic activities namely production of crude oil and its products, their transport, ship traffic, etc. Prominent land-based sources are domestic and industrial effluents, atmospheric fallout of fuel combustion products, condensed vapours etc. PHc can cause severe damage to the aquatic life when there are sudden discharges in large quantities during accidents such as tanker collision, pipeline rupture, fire etc

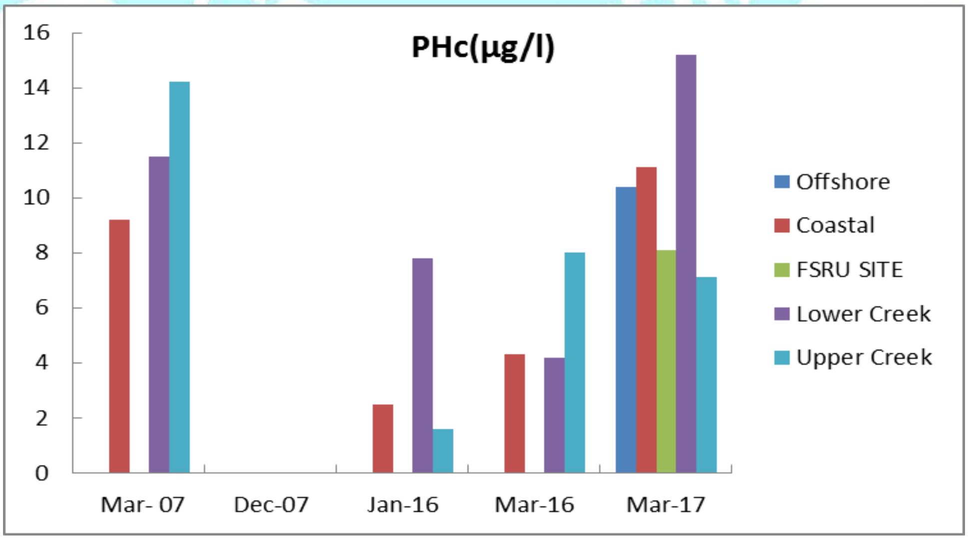
The average concentration (µg/l) of PHc at different locations in the study area varied as given in the table below:

Station	PHc(µg/l)
J1	5.7*
J2	10.7*
J3	8.8
J4	12.9
J5	17.4
J6	7.6
J7	10.4*
J8	19.2*
J9	9.4
J10	6.7*

*Single value

The above table indicates that the PHc values during present study varied randomly with no clear trends and the values ranged from 5.7 µg/l to 19.2 µg/l. These values are lower than recommended for water quality criteria (0.1 mg/l in terms of oil & grease) for designated best use for salt pans, shell fishing, marine cultures and ecologically sensitive zones by the Central Pollution Control Board (CPCB).

The long-term average variations in PHc (µg/l) (2010-2017) are given in the Figure below:



The earlier measurement available for the region is of March 2007 wherein the average values of PHc in the range 8.5-14.0 µg/l were recorded. In the subsequent years the values varied widely with no evidence for any systematic increase with time. However, higher concentration of PHc recorded in the lower estuarine zone may be due to boat activities in Jaigarh area.

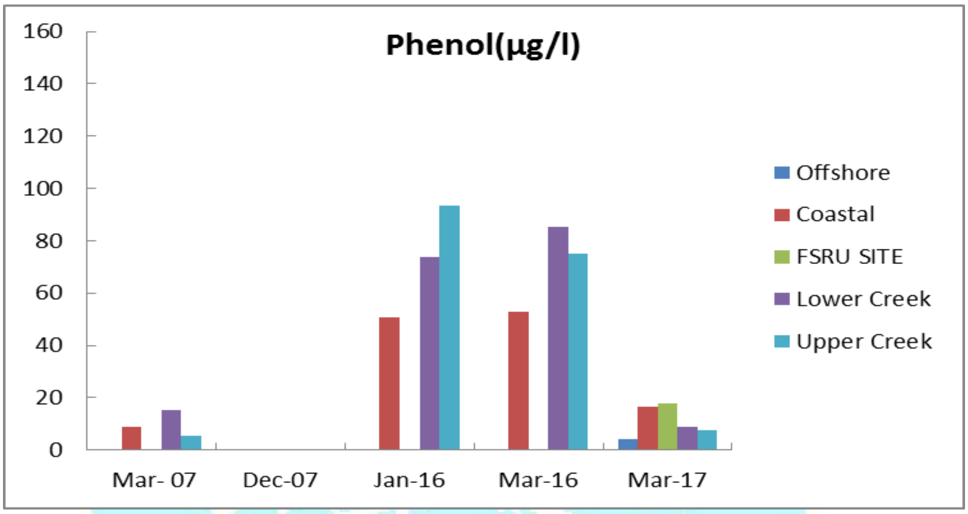
4.4.9 PHENOLIC COMPOUNDS

Phenols in natural waters generally originate through anthropogenic discharges. They are used extensively in fungicides, antimicrobials, wood preservatives, pharmaceuticals, dyes, pesticides, resins etc and hence they become important constituent of domestic and organic industrial effluents. Phenols have broad spectrum toxicity depending upon the substitution. During present study concentration of phenol ranged from 2.6 µg/l to 38.9 µg/l. Average concentration of phenols recorded during present study is given in the Table below:

Station	Phenol (µg/l)
J1	38.9*
J2	13.9*
J3	3.0
J4	11.6
J5	6.2
J6	7.6
J7	4.3*
J8	10.7*
J9	20.4
J10	15.1*

*Single value

As evident from above table, the concentration of phenol was in the range, generally recorded in the nearshore coastal waters. Comparison of results recorded during different sampling events is presented graphically below: Thus the concentration of phenols was lower than the earlier results.



4.5 ASSESSMENT OF SEDIMENT QUALITY

Several contaminants on entering the aquatic environment are adsorbed by SS in water and transported to the sediment on settling. Thus the sediment of areas receiving anthropogenic pollutants such as trace metals, hydrocarbon residues, chlorinated pesticides etc sustain high concentration of pollutants relative to the baseline. Hence, aquatic sediments are useful indicators of anthropogenic pollution The results of sediment analysis are presented in Table 4.5.1.

4.5.1 TEXTURE

The texture of sediment generally influences the concentration of trace metals and other trace constituents. Thus, sediments with high clay content often exhibit relatively high levels of trace constituents by virtue of the availability of large surface area for their absorption from the water column.

The result of texture analyses revealed that the sediment of stations J2 was sandy (42.1%) whereas the sediment at other stations was predominantly silt (28.4-85.0%). The clay content varied considerably and ranged from 10.4 to 53.9% at the subtidal stations. Location wise texture of study region varied as given in the table below:

March 2017			
Station Code.	Sand (%)	Silt (%)	Clay (%)
J1	1.0	45.1	53.9
J2	42.1	28.4	29.5
J3	34.5	31.4	32.6
J4	26.7	62.7	10.6
J5	2.2	68.0	29.8
J6	16.3	50.3	33.4
J7	1.6	68.6	29.8

J8	2.2	69.6	28.2
J9	3.6	85.0	11.4
J10	5.0	84.6	10.4

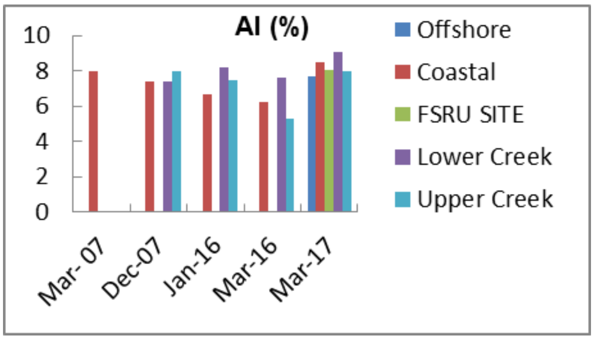
4.5.2 HEAVY METALS

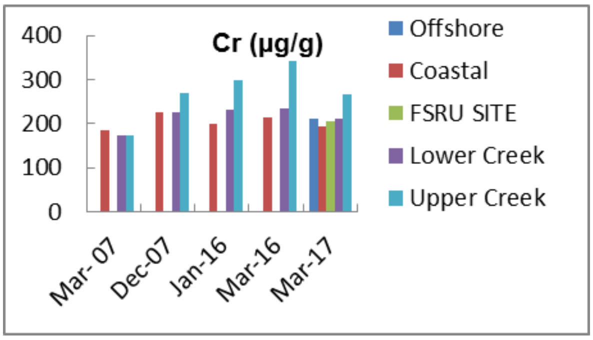
Bed sediments of uncontaminated coastal areas have metal concentrations which are derived from rocks and soils of the surrounding landmass which form the baseline. Apart from texture, the concentration of trace metals in sediments also depends on the iron and manganese content.

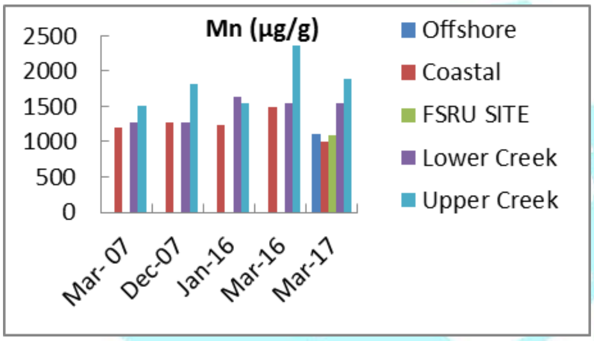
Concentration of metals of concern analysed during the present study are presented in the table below:

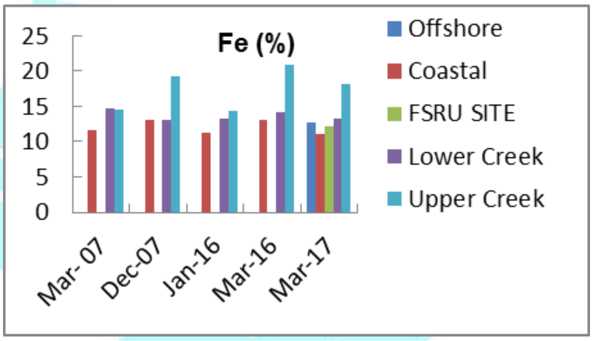
As evident from the above table, the sediment of study area sustain high concentration of Al (6.6 -9.9%) and Fe (10.0-18.1%), indicating naturally occurring high concentration of the metals. Other metals also were present in association with Fe. Thus Cr was in the range 182-266 µg/g. The highest concentration of Cr (266 µg/g) was at J6, where Fe was also highest (18.1 %). Similarly, Co (114 µg/g), NI (98 µg/g), Cu (323 µg/g) and Zn (214 µg/g) showed highest concentration at same location. Thus indicating the lithogenic origin of metals in the study region.

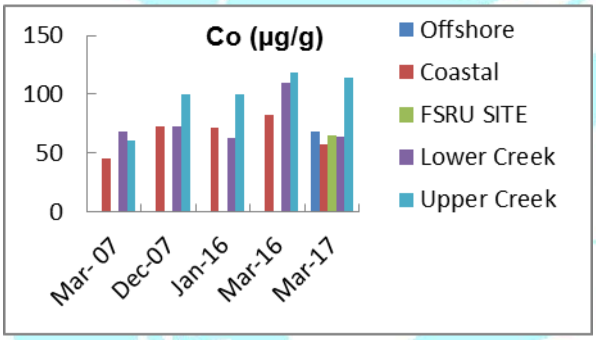
The metal concentration recorded during 2017 is compared with earlier results in the figures below:

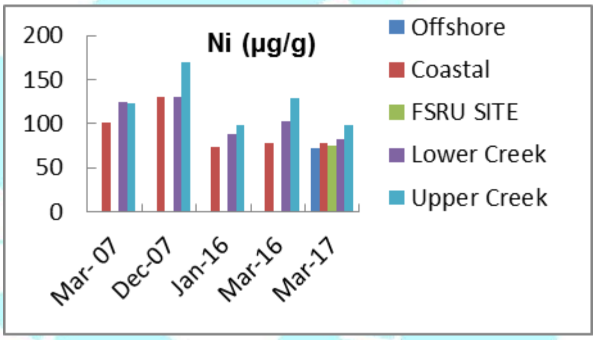

Al (%)
10
8
6
4
2
0
Mar-07
Dec-07
Jan-16
Mar-16
Mar-17
Offshore
Coastal
FSRU SITE
Lower Creek
Upper Creek

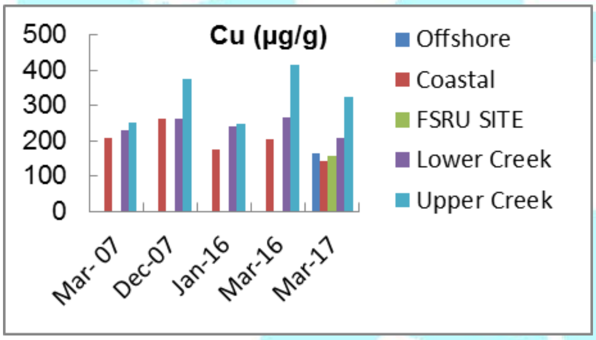

Cr (µg/g)
400
300
200
100
0
Mar-07
Dec-07
Jan-16
Mar-16
Mar-17
Offshore
Coastal
FSRU SITE
Lower Creek
Upper Creek

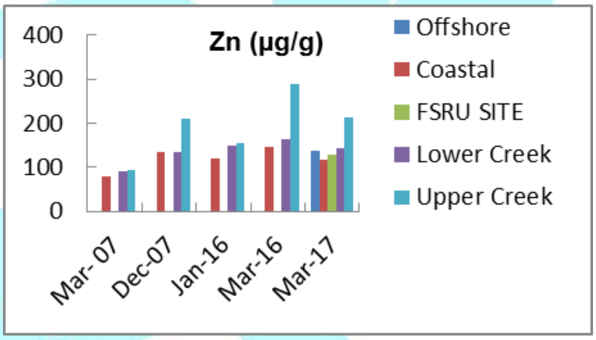

Mn (µg/g)
2500
2000
1500
1000
500
0
Mar-07
Dec-07
Jan-16
Mar-16
Mar-17
Offshore
Coastal
FSRU SITE
Lower Creek
Upper Creek

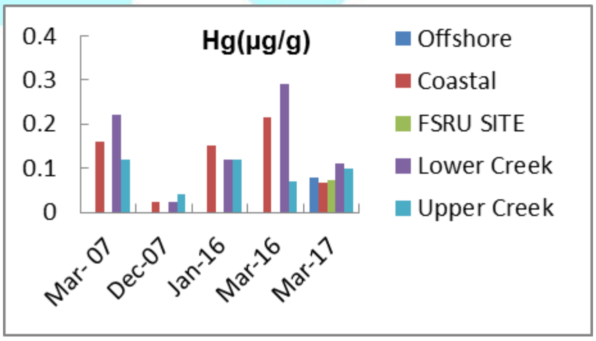

Fe (%)
25
20
15
10
5
0
Mar-07
Dec-07
Jan-16
Mar-16
Mar-17
Offshore
Coastal
FSRU SITE
Lower Creek
Upper Creek


Co (µg/g)
150
100
50
0
Mar-07
Dec-07
Jan-16
Mar-16
Mar-17
Offshore
Coastal
FSRU SITE
Lower Creek
Upper Creek


Ni (µg/g)
200
150
100
50
0
Mar-07
Dec-07
Jan-16
Mar-16
Mar-17
Offshore
Coastal
FSRU SITE
Lower Creek
Upper Creek


Cu (µg/g)
500
400
300
200
100
0
Mar-07
Dec-07
Jan-16
Mar-16
Mar-17
Offshore
Coastal
FSRU SITE
Lower Creek
Upper Creek


Zn (µg/g)
400
300
200
100
0
Mar-07
Dec-07
Jan-16
Mar-16
Mar-17
Offshore
Coastal
FSRU SITE
Lower Creek
Upper Creek


Hg(µg/g)
0.4
0.3
0.2
0.1
0
Mar-07
Dec-07
Jan-16
Mar-16
Mar-17
Offshore
Coastal
FSRU SITE
Lower Creek
Upper Creek

The results indicated considerable variation of trace metals of concern such as chromium, nickel, copper, zinc and mercury along the estuary and coastal region and. The coastal sediment of the Ratnagiri district being largely derived from the lateritic and basaltic terrain, is high in Fe and Mn and other trace metals and observed values can be considered as baseline in the absence of sibnificant anthropogenic source to the coastal area of Jaigarh.

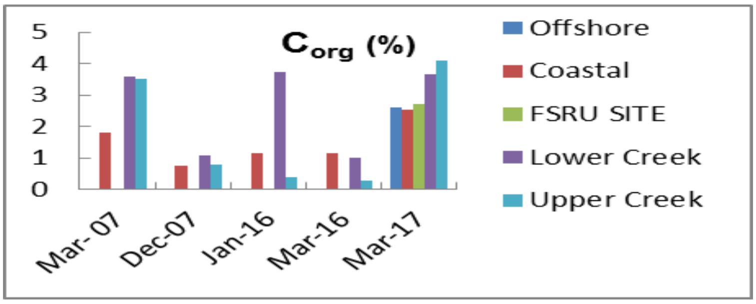
4.5.3 ORGANIC CARBON

Generally, organic matter in natural coastal aquatic sediments originates from terrestrial runoff and remains of organisms inhabiting the region. Anthropogenic organic inputs such as through sewage can increase the content of organic matter to abnormal levels in sediments. Organic matter settling on the bed is scavenged by benthic organism 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 levels of (C_{org}) in the sediment of the study region varied as follows:

C_{org} (%)	
Station	**March 2017**
J1	2.7
J2	2.5
J3	2.3
J4	2.9
J5	4.4
J6	4.1
J7	2.6
J8	2.7
J9	2.9
J10	2.5

Thus the sediment of the study region sustained C_{org} in the range 2.3-4.4%. The coastal sediment of South Maharashtra contain higher percentage of C_{org} as compare to north Maharashtra and the values off Jaigarh are in the expected range.

The C_{org} content in sediment of the study area during 2007-17 is illustrated in the following figure.



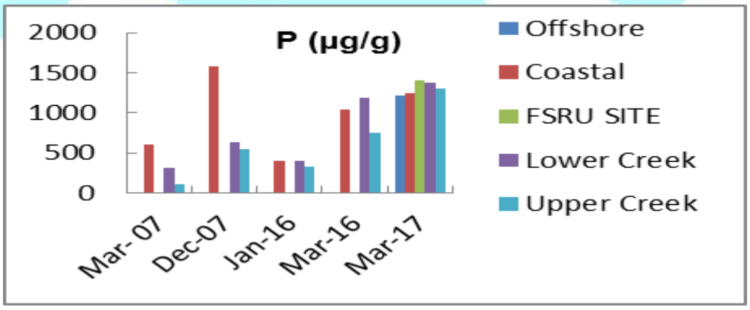
Results presented in the above figure and those recorded during the present study indicate high natural variability probably due to the textural differences of the sediment.

4.5.4 PHOSPHORUS

Naturally occurring phosphorus in marine sediments is derived from the geological sources through which the 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 sediment of study area varied as given below:

Station	March 2017
J1	1702
J2	1094
J3	1162
J4	1268
J5	1499
J6	1309
J7	1349
J8	1020
J9	1222
J10	1472

The past results of phosphorus in sediments of the study area are presented in the figure below:



The long term data indicate that the concentration phosphorus was variable due to differing sediment texture.

4.5.5 PETROLEUM HYDROCARBONS

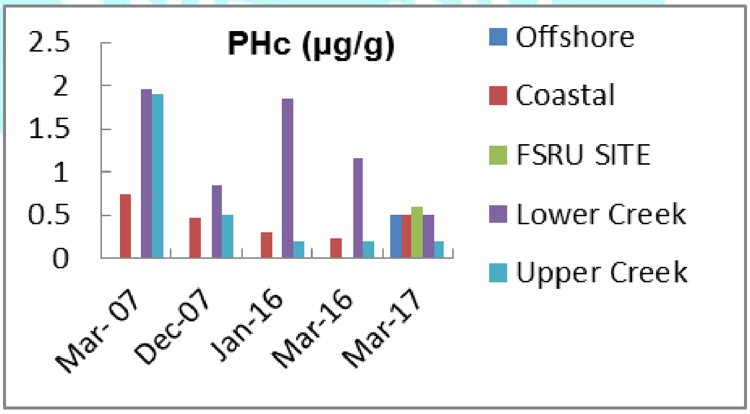
Though large accidental releases of oil are easily sighted as slicks on the sea surface, minor chronic releases such as through effluents often go unnoticed. Petroleum in the marine environment undergoes weathering leading to its removal from the sea surface and the residue left after the petroleum weathers, is adsorbed by suspended particulates and ultimately transferred to the sediment. Hence, sediment serves as useful indicator of cumulative effect of oil contamination.

The concentration of PHc (µg/g; wet wt) in the study area varied as follows:

Station	March 2017
J1	0.3
J2	0.4
J3	0.8
J4	0.8
J5	0.2
J6	0.2
J7	0.5
J8	0.5
J9	0.7
J10	0.5

Normal levels of PHc in coastal sediments with no chronic source of petroleum hydrocarbons are generally below 1 µg/g (wet wt). During present study the concentration of PHc was <0.8 µg/g (wet wt).

The concentration of PHc in sediment off Jaigarh during 2007-2017 is presented in the following figure:



From these results it can be concluded that the concentration of PHc in study region has remained low, but variable. The results are comparable with the levels normally recorded in sediments off the west coast of India and reveal the absence of significant PHc accumulation in the sediment of the region.

4.6 FLORA AND FAUNA

Apart from changes in the physico-chemical characteristics of water and sediment that a coastal development may induce, the ultimate concern is invariably the biological resource. The important natural factors which influence flora and fauna in coastal areas are tides, currents, freshwater flow, and water quality and sediment characteristics. Monsoon brings about drastic changes in salinity in estuaries and can exert a marked influence on the flora and fauna of tropical brackish water ecosystems.

Floral and faunal components in estuaries and coastal waters are highly diverse inhabiting a variety of ecosystems. 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 anthropogenic 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.

Important biological parameters which are considered for assessment in the present study are bacteria, phytoplankton, zooplankton, benthos, corals, mangroves, reptiles & mammals, fishes and birds. 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 warning of potential damage. Fishery status assessed based on the data obtained from the Maharashtra Fisheries Department provides information on the fish composition and hence commercial potential of a water body. A collective evaluation of all the above components is a reliable approach to predict the state of equilibrium of aquatic life in marine and estuarine ecosystem of Jaigard.

4.6.1 BACTERIA

The principle source of water borne diseases such as cholera, typhoid and hepatitis, is contamination of water by sewage and animal wastes. Apart from potable water, bacterial contamination occurs in surface waters such as those used for fisheries and recreational uses. Though 90% of intestinal bacteria die out within 2 days in natural waters, the remaining 10% decline much more slowly. Coliform bacteria such as *Escherichia coli* and faecal*Streptococcus sp.* are the 2 most important groups of non-pathogenic bacteria found in sewage.

Because of number of problems associated with the determination of population of individual pathogens, non-pathogenic bacteria (such as coliforms) are used as indicators of water pollution. Untreated domestic waste water has about 3 million coliforms per 100 ml. Since pathogens originate from same source the presence of coliforms indicate potential danger. For water used for swimming and recreation the standard is 200/100ml of FC and 1000/100ml of TC (USEPA, 1986).

Bacteriological analyses for the present study included the enumeration of total viable bacterial counts (TVC) and coliforms in premonsoon seasons at 10 stations covering the estuarine part and coastal region. Total Viable Counts (TVC), Total Coliform (TC), *Escherichia coli* like organisms (ECLO) and *Streptococcus faecalis* like Organism (SFLO) were studied.The microbiological results for water and sediments are given in the Table 4.6.1 to 4.6.2.

i) Water

The total viable bacterial populations (TVC) in the water samples ranged widely from 40 x 10^2CFU/ml to as high as 28000 x 10^2CFU/ml. (Table 4.6.1). Total coliforms and fecal coliforms which are indicators of fecal pollution were below the detectable limits almost at all the sampling sites.Pathogenic organisms such as *Salmonella* like organisms, Shigella like organisms and Vibrio like organisms were present at majority of the sampling sites but were present in higher numbers at Stations J2, J3, J4 and J6.

ii) Sediment

The total viable bacterial populations in sediments ranged widely from 100 x 10^2CFU/ml to as high as 27000 x 10^2CFU/g. (Table 4.6.2). Total coliforms and fecal coliforms which are indicators of fecal pollution were below the detectable limits almost at all sampling sites. Fecal indicator bacteria like *Escherichia coli* and *Streptococcus fecalis* were also below the detectable limits. Pathogenic organisms such as Salmonella like organisms, Shigella like organisms and Vibrio like organisms were sparsely distributed at majority of sampling sites but were present in higher numbers at Stations J4, J5, J6 and J8. From the enumeration of bacterial counts, it is inferable that the populations of different bacteria are in the general ranges reported in coastal waters that experience low anthropogenic influence.

4.6.2 PHYTOPLANKTON

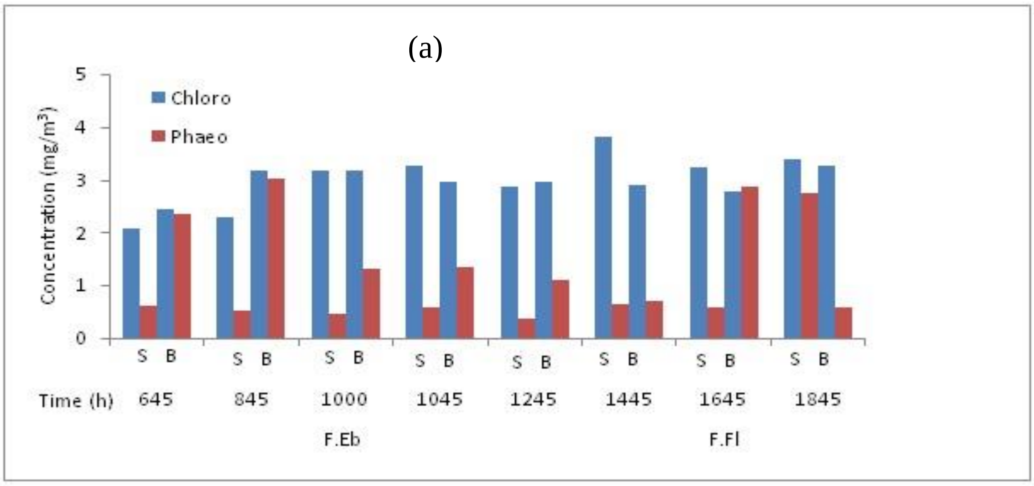
Phytoplankton being primary producers plays a major role in synthesizing organic carbon using inorganic nutrients, carbon dioxide and sunlight in the marine environment. Hence, they are the basic component of food chain and play an important role in the ecological assessment of a marine ecosystem.

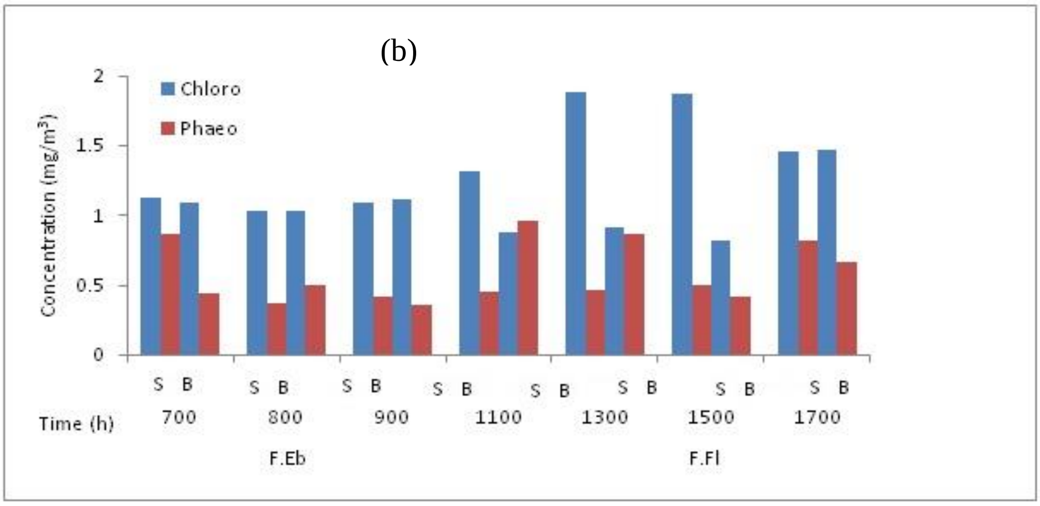
A normal ecosystem with a natural balance between different trophic levels viz. primary, secondary and tertiary productions gets disturbed and imbalanced of its food chain due to anthropogenic pollutants. An ecosystem receiving domestic wastewaters could lead to an unwanted algal proliferation or bloom associated with alteration in community structure of phytoplankton.

a) **Phytopigments:** Phytoplankton biomass was evaluated in terms of phytopigments and population in terms of cell counts. In the natural coastal marine environment of India the concentration of chlorophyll a is commonly below 5 mg/m^3. The results are presented in Tables 4.6.3 to 4.6.5 and Figure 4.6.1. During March 2017, the distribution of chlorophyll *a* was patchy with values fluctuating from 0.3 to 5.1 mg/m^3 (av. 0.4 to 4.1 mg/m^3). Stations J5 and J6 sustained higher chlorophyll concentration (4.7 and 5.1 mg/m^3) due to proximity to shore where high nutrient was found. Low oncentration of chlorophyll a (0.3 mg/m^3) was at station J7 as well as stations J1 and J2 (0.7 mg/m^3) because both the stations were located on the offshore area where it faces high tidal and current activity which hamper the phytoplankton growth. Phaeophytin, the degraded product of chlorophyll *a,* was generally in low concentration than chlorophyll *a* except some sporadic high values (2.8 and 3.0 mg/m^3).

The relative concentrations of phytopigments indicate an environment conducive to the growth of phytoplankton. The ratios of chlorophyll *a* phaeophytin showed random variations. However, the ratios at all the station was more than 1.0 which suggests favourable condition for phytoplankton growth.

Temporal variation of Chlorophyll a and pheophytin recorded at stations (a) J4 and (b) J9 are presented in the figures below:





As it is evident from above figures, the concentration of chlorophyll *a* was high at station J4 and at station J9. During full flood period chlorophyll *a* was found to be high.

b) Population: The distribution of phytoplankton cell count (8.8 x10^3- 470 x10^3/l; av. 269.8 x10^3/l) also revealed variability in their populations (Table 4.6.4). The trend in population distribution is similar to the variation in phytopigments with the highest population density (470.0x10^3/l) at station J6. Overall, 51 genera of phytoplankton were identified (Table 4.6.5) though all of them were not encountered at any single location. Generic diversity varied between 7 %. and 23 %. (avg.10 %.). Highest genera encountered at station J6 (32 nos.) in the surface water. The overall average highest percentage composition of phytoplankton in the study region were; *Cylindrotheca* sp. (15.2%), *Dactyliosolen* sp. (14.8%), *Rhizosolenia* sp. (4.8%), *Skeletonema* sp. (4.8%) (Table 4.6.5).

Similar to chlorophyll *a*, the distribution of phytoplankton population revealed the temporal and spatial variation with higher levels in near shore water than the offshore. Overall the results of phytoplankton revealed a good productivity both in terms of phytoplankton biomass and population with fairly good generic diversity.

Comparing the standing stock of phytoplankton of the present studies with previous data collected in the pre- and post-monsoon 2007 and 2016, it was evident that all the three segments like coastal waters, lower estuary and upper estuary sustained comparably high standing stock of phytoplankton during premonsoon 2017. The phytoplankton biomass, population and total genera of the FSRU site (stations J9 & J10) fell between the ranges of earlier observations (Table.4.6.6).

4.6.3 MANGROVE ECOSYSTEM

Mangroves are salt tolerant forest ecosystem of tropical and subtropical intertidal regions. Where conditions are sheltered and suitable, mangroves may form extensive and productive forest, 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 of land by sea is well recognised thus minimizing water logging and formation of saline banks. There were no mangroves at and near the proposed project site. However, mangroves are present in the Shastri Estuary around 9.0 km away from the proposed FSRU sites which are listed in the Table below:

Table 4.6A: List of mangroves in Shastri Estuary

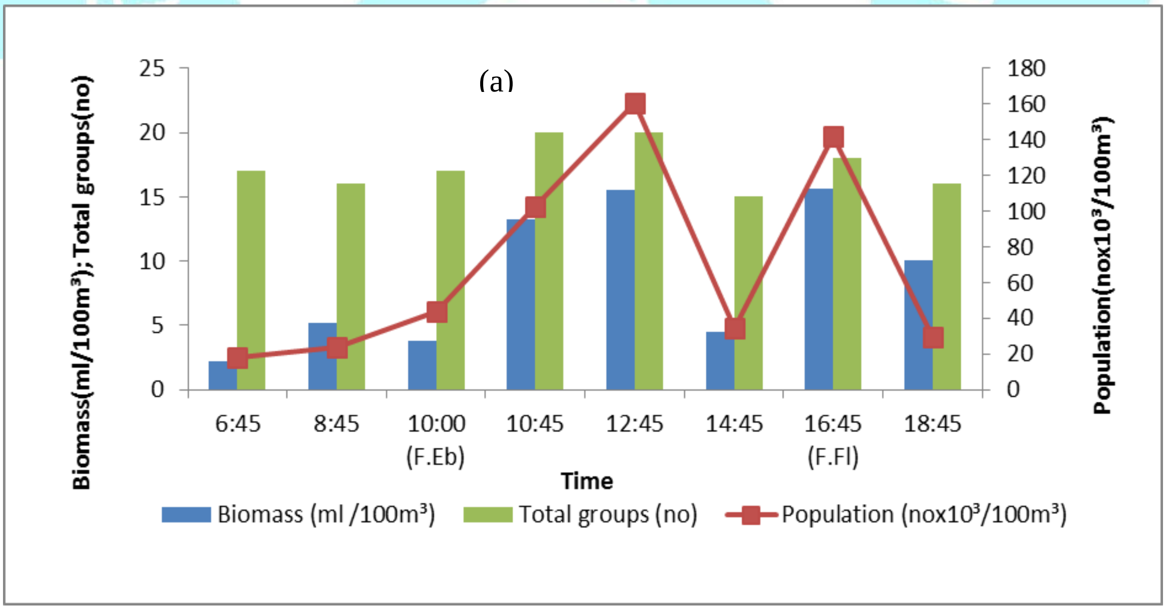
Sr. No.	Scientific name
1.	*Aegiceras corniculatum*
2.	*Avicennia marina*
3.	*Avicennia officinalis*
4.	*Bruguiera gymnorrhiza*
5.	*Ceriops tagal*
6.	*Lumnitzera racemosa*
7.	*Rhizophora apiculata*
8.	*Rhizophora mucronata*
9.	*Sonneratia alba*
10.	*Sonneratia apetala*
11.	*Sonneratia caseolaris*
12.	*Sonneratia griffithii*

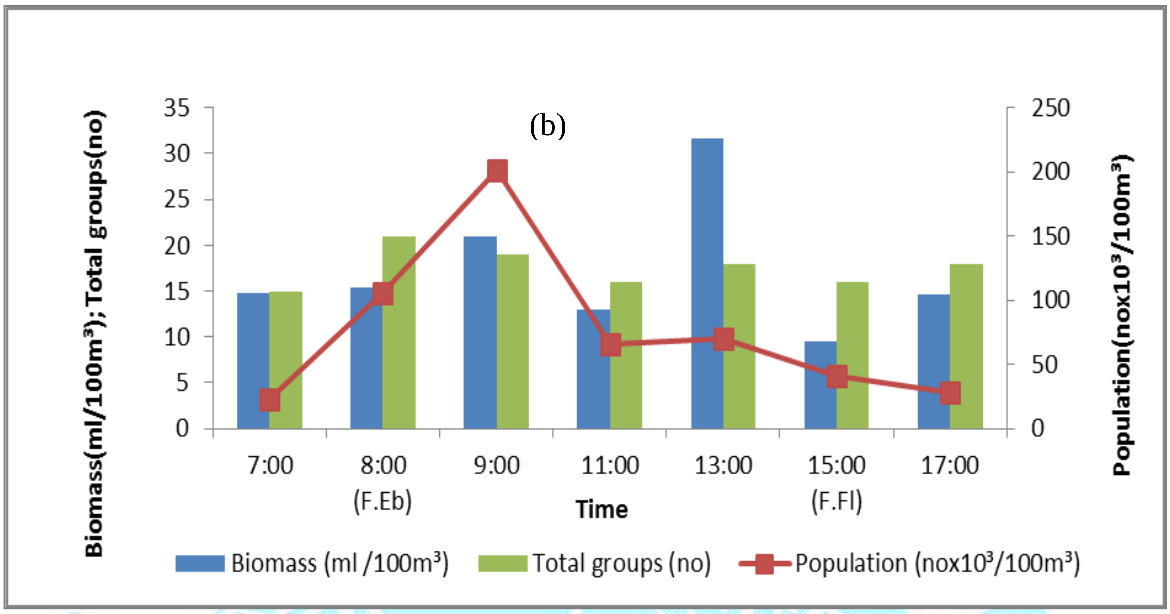
4.6.4 ZOOPLANKTON

Zooplankton by virtue of its food values to higher animals form a vital link between phytoplankton and fish and hence is an indicator of fish productivity of a marine area. Their standing stock in terms of average biomass (23.4 ml/100 m^3) and average population (90.7 $x10^3$/100 m^3) varied widely (Table 4.6.7 and 4.6.8) and was indicative of an overall good secondary production potential of the region during the study period. The results indicate wide variations in the standing stock of zooplankton throughout the study area. The percentage composition of zooplankton consisted of high population of copepods (av. 86.4%), decapod larvae (av. 2.6%), *Siphonophores* (av. 3.1%) and *lamellibranchs* (av. 2.2%) (Table4.6.9). The composition is fairly diverse and the number of faunal groups varied between 15 and 21(Table 4.6.8).

Overall 21 groups of zooplankton were observed; the major groups being *copepods, gastropods, Siphonophores, lamellibranchs* and *lucifer*. However, at no time all the groups were present at a single station (Table 4.6.10). Temporal variation in zooplankton biomass, population and total group at station J4 (Table 4.6.7) varied widely with biomass and population in the range 2.2-15.6 ml/100 m^3 and 17.9-160.3 no x 10^3/100m^3 respectively.

Temporal variation of mesozooplankton biomass, population density and total genera recorded at stations (a) J4 and (b) J9 are presented in the figures below:





As it is evident from above figures, mesozooplankton biomass, population density and total genera was found to be high from ebb to flood and full flood except at 1445hrs at J4 while at J9 full flood showed comparative low population density.

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.

Decapods: This group was an important constituent of zooplankton. Decapod larvae occurred in most zooplankton samples and contributed about 2.61% (av) to the zooplankton population (Table 4.6.9). Stages of *Lucifer* sp. (1.5 %) also occurred in good numbers.

Fish eggs and larvae: Fish larvae (av <0.1%) were low in number in the zooplankton samples. Fish eggs (av. 0.2%) though at a low percentage, were encountered in most zooplankton collections. In general, the study area sustained low numerical abundance of fish larvae probably because the study area was not the breeding grounds of fishes.

It is evident from the data that the zooplankton productivity in terms of biomass and population varied widely in each segment, as commonly observed for coastal areas under high tidal influences. Comparing with the standing stock of zooplankton of the present observation with previous data of pre- and post-monsoon 2007 and 2016, it was evident that all the three segments like coastal waters, lower estuary and upper estuary sustained comparably high standing stock of zooplankton during premonsoon 2017. The zooplankton biomass, population and total group of FSRU site (stations J9 & J10) fell between the ranges of earlier observations (Table 4.6.11).

4.6.5 BENTHIC FAUNA

4.6.5.1 MACROBENTHOS

Samples for macrobethos were obtained from subtidal zones for the estimation of macrobenthic density, biomass and composition.

Subtidal macrobenthos: The faunal standing stock of benthic macrofauna in terms of population and biomass varied in a wide range (Table 4.6.12).The range and average of faunal standing stock and composition of subtidal macrobenthos are given below:

Station J5 recorded relatively high macrobenthic standing stock in terms of biomass and station J1 in terms of population due to dominance of polychaetes and amphipods at stations J5 and J1 respectively. Major faunal component in the study area were polychaetes followed by amphipods (Table 4.6.13). Overall, 22 faunal groups were recorded in the area though on no occasion all groups were present at a given station.

It is evident from the data that the benthic productivity in terms of biomass and population varied widely in each segment, as commonly observed for coastal areas under high tidal influence. Comparing with the standing stock of macro benthos of the present observation with the previous data of pre- and post-monsoon 2007 and 2016, it was evident that all the three segments sustained comparably high standing stock of zooplankton during premonsoon 2016. The macrobenthos biomass, population and total group of FSRU site (J9 & J10) fell between the ranges of earlier observation (Table4.6.14)

4.6.5.2 MEIOBENTHOS

Samples for meirobethos were obtained from the subtidal zones for the estimation of meiobenthic density, biomass and composition.

The faunal standing stock of benthic meiofauna in terms of population and biomass varied in a wide range (Table 4.6.15).Station J5 recorded relatively high meirobenthic standing stock in terms of biomass and station J2 in terms of population due to dominance of nematodes, foraminiferans and copepods. Major faunal component in the study area were nematodes followed by foraminiferans (Table 4.6.16). Overall, 18 faunal groups were recorded in the area.

4.6.6 FISHERY

Prevailing fishery status of the region around Jaigarh was evaluated based on experimental fishing and on the basis of data from the Department of Fisheries, Government of Maharashtra. Jaigarh comes under Ratnagiri fishing zone of Ratnagiri district. As per 2014-15 report, total marine fish landing of Ratnagiri district was 24.82% of total fish production of Maharashtra. Fish catch of Ratnagiri zone was 3.94% of total Marine fish production of Maharashtra. Jaigarh stands highest in marine fish landing in Ratnagiri zone with 34.54% of zonal fish landing, 5.49%, 5.49% of Ratnagiri district and 1.36% of total marine fish landing of the state. There were 80 mechanized and 75 non-mechanized boats in the Jaigarh region. In Ratnagiri district mainly trawl net, gillnet, longlines, Purseine and bagnets are being used for commercial fishing. Yearly species wise fish landing of the Ratnagiri district is given in the Table 4.6.17 to 4.6.25.

Experimental fishing was carried out during March 2017 off Jaigarh (Plates 3-4) to assess the fishery potential in the mouth region of the Shastri estuary. The result indicated low fish catch rate with 2 kg/h.

The catches were represented by species .*Parastromateus niger*, *Parastromateus argenticus*, *Uroconger lepturus*, *Scomber microlepidotus*, *Cynoglossus clubius*, *Alectis cilioris*, *Nemipterus japonicas*, *Loligo, Sepia, Sciaena marleyi, Thryssa dussumeri*.

4.6.7 CORALS AND ASSOCIATED BIOTA

Corals are absent off Jaigarh. In fact the area sustains high percentage of silt and clay – the conditions unfavorable for the reef-building corals to thrive.

4.6.8 BIRDS

The Jaigarh creek and its immediate environs support a large number of Sea bird species. According to local fishermen the Flamingoes (*Phoenicopterus ubber*) are among the winter visitors to the Jaigarh creek. The wooded slopes bordering the Jaigarh creek and sea-coast are also home to several species of endemic birds such as hornbills.

The area provides wintering habitat for a variety of migratory water birds from South America and Australia and south Asian regions. Besides that, it also provides a resting site for several water birds migrating through north-west India to south Indian and South Africa wintering grounds. A list of water birds of Jaigarh is given in the Table below:

Table: 4.6B: Lists of birds observed in the study area during March 2017

Sr. No.	English name	Scientific name
1.	Pond Heron	*Ardeola grayii*
2.	Whimbrel	*Numenius phaeopus*
3.	Common Green shank	*Tringa nebularia*
4.	Eurasian Kestrel	*Falco tinnunculus*
5.	Osprey	*Pandion haliaetus*
6.	Crested Serpent-Eagle	*Spilornis cheela*
7.	Black Serpent-Eagle	*Elanus caeruleus*
8.	While bellied Sea-Eagle	*Haliaetus leucogastea*

4.6.9 REPTILES AND MAMMALS/ENDANGERED SPECIES

Reptiles were not spotted in the study area. Dolphins (*Delphinus delphis*) were recorded in the region during the study period. No endangered species were recorded during the course of this study.

4.7 BATHYMETRY AND PHYSICAL PROCESSES

The physical processes influencing dynamics of estuaries and coastal zones are tides, currents, waves and land runoff while bathymetry provides information on the water depth. The information of these parameters is necessary while assessing the impacts of coastal developments on the aquatic environment.

4.7.1 BATHYMETRY

NHO chart (No. 2011) gives the bathymetry of the Jaigarh region and other relevant information. Coastal Jaigarh consists of Damankul Bay with the Jaigarh head to the west of the Bay. Near JSW port area, 10 m contour is located at 0.5 Km from the low tide line. However, north of the Jaigarh head consists of Narwan Bay and the distance of the low tide line from the 10 m contour is around 3 Km.

In the middle of these two bays, river Shastri is joined and at the mouth of the Shastri estuary low depth of around 2.5 m below CD are found. However, at Jaigarh fort depth of more than 15 m are available. Large mudflats are situated in the estuarine zone in the southern side.

There is another bay, Ambwah Bay, is situated in the south of the Jaigarh head. In this bay, the distance between 10 m contour and the low tide line is 1.25 Km. From 10 m contour onwards, other depth contours run parallel to the coast.

4.7.2 TIDES

The tide is one of the most important phenomenon that controls the dynamics of a coastal water body. Tides in the region are generally mixed semi-diurnal type with two unequal high and low water occurring each tidal day. Recorded tide at Jaigarh at station J9 from 02 - 09 March 2017 is shown in Figure 4.7.1. The spring tidal range was 2.4 m while neap range was around 1.2 m. Tide was also measured at same location from 10.08.2015 to 22.09.2015 and shown in Figure 4.7.2. This data indicates that the spring tidal range was 3.0 m and neap range was 1.0 m. This shows that maximum tidal range at this location is 3 m. The average time lag between Apollo Bunder and Malvan was 1h 10 min in spring and 2 h in neap.

4.7.3 CURRENTS AND CIRCULATION

Currents were measured at station J9 from 10.08.2015 to 22.09.2015. The results are presented in Figure 4.7.3. Maximum current observed in the region was 0.55 m/s. The direction veered between 50º and 300º. This indicate that the currents changed from NE to NW direction in a tidal cycle which shows that the current were parallel to the coastline.

Generally drogue study is conducted to study the excursion length of a particle in a particular tidal period (Ebb/Flood). Neutrally buoyant drogue was released at a predetermined location (station J9) and was tracked in a mechanized boat over a period of time. The position of the drogue with respect to time was plotted to obtain its trajectory. The drogue was released just at the commencement of high tide and low tide. The results of drogue trajectories are plotted in Figures 4.7.4 and 4.7.5. The results indicate excursion length of 5.4 km in 4h 15 min in the flood condition while it was 3.5 km in 5h 30 min during ebb. Hence a particles released at station J9 would move in the Shastri estuary during flood and southward along the coast when released during ebb.

4.7.4 WAVES

The wave data pertaining to the Jaigarh is sparse. However, the data at Ratnagiri coast which is 35.5 km away from the Jaigarh coast is available. The earlier data indicates that the significant wave height ranged from 0.2 to 4.2 m with an average of 1.1 m. In case of wave period, it varied between 3.8 and 15.0 s with an average of 7.3 s. The wave power ranged from 0.2 to 80.3 k W/m with an average of 7.6 k W/m. The wave data was recorded during

10.08.2015 to 22.09.2015 off Jaigarh and presented in Figure 4.7.6. The results show that the wave height ranged between 0.4 and 1.8 m.

4.8 NUMERICAL MODELING OF HYDRODYNAMICS AND DISPERSION

4.8.1 NUMERICAL MODELING

As discussed in Section 2.1 it is proposed to use open loop re-gasification technology or closed loop heating, In the former case, warm seawater is drawn as a heat source to vaporize LNG and in the process the temperature of the seawater is lowered as compared to the ambient seawater temperature. In close loop option the FSRU could employ another heating fluid to regasify the LNG without use of sea water. In this case, sea water is used only for machinery cooling.

In case of open loop option, the volume of seawater required for vaporize LNG is estimated at 15000 m^3/h and equivalent volume has to be released to the sea at temperature 7°C below that of the ambient seawater (cold water effluent). Seawater (2000 m^3/h) will also be used to cool the FSRU machinery and discharged to the sea with temperature 6°C above the ambient seawater temperature (warm water effluent). Seawater intake and effluent release are integral to the design and construction of FSRU and is directly withdrawn / released from the ship's hull. An average temperature of 28.5°C has been considered as ambient temperature for modeling the dispersion of cold/hot water.

Since the locations of intake of seawater and release of effluents is integral to a FSRU, hypothetical locations – one each, for the intake of sea water and for discharge of the cold water effluent were selected for detailed modeling study. The outfall location for discharge of cold water effluent is at coordinates: 17°18'36.8" N; 73°11'42.0" E which is to the west of the warm water effluent discharge site at a distance of approximately 270 m. The proposed locations of the cold and the warm effluents are shown in Figure 4.8.1.

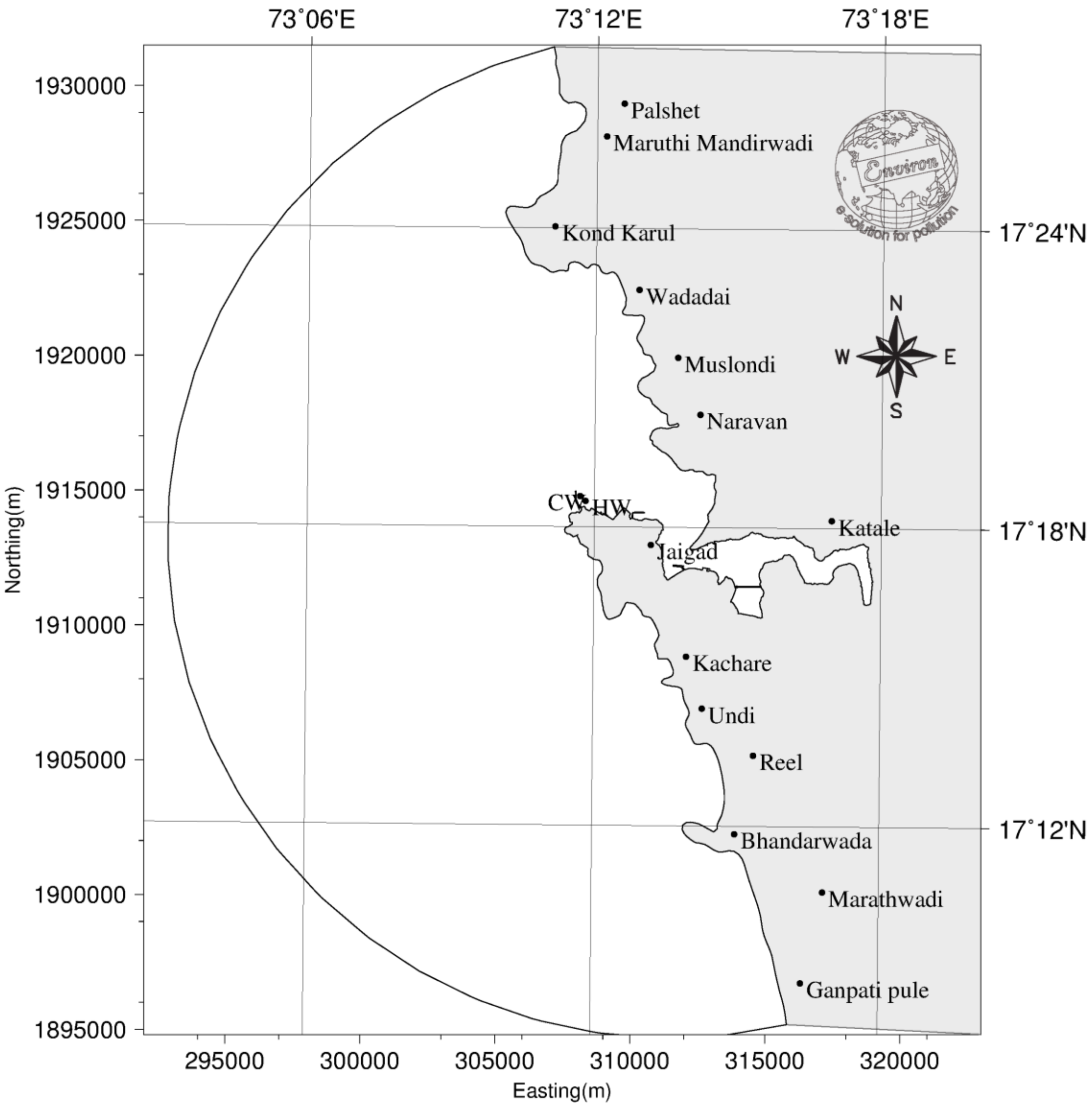


Figure 4.8.1:Locations of proposed outfalls (Cold Water and Hot Water)

Thus the main objectives of these studies are as follows:

- Simulate the flow conditions prevailing at the site based on the bathymetry and tidal conditions.
- Calibrate the model with the available field data on tides and currents.
- Predict the flow conditions at site considering the seawater intake and discharge of return sea water from the FSRU at proposed locations.
- Predict dilution and dispersion of return seawater when released to the sea.

4.8.2 HYDRODYNAMIC MODEL

4.8.2.1 BASIC GOVERNING EQUATIONS

The basic governing equations of flow are solved numerically in simulation of tides and currents in the coastal environments. These are:

Continuity equation

$$\frac{\partial \eta}{\partial t} + \frac{\partial uH}{\partial x} + \frac{\partial vH}{\partial y} = 0$$

Momentum equations

The two depth-averaged momentum equations can be written as

$$\frac{\partial uH}{\partial t} + \frac{\partial u^2 H}{\partial x} + \frac{\partial uvH}{\partial y} = fvH - gH\frac{\partial \eta}{\partial x} + H\frac{\partial}{\partial x}\left(K_x \frac{\partial u}{\partial x}\right) + H\frac{\partial}{\partial y}\left(K_y \frac{\partial u}{\partial y}\right) + \tau_{wx} - \tau_{bx}$$

$$\frac{\partial vH}{\partial t} + \frac{\partial vuH}{\partial x} + \frac{\partial v^2 H}{\partial y} = -fuH - gH\frac{\partial \eta}{\partial y} + H\frac{\partial}{\partial x}\left(K_x \frac{\partial v}{\partial x}\right) + H\frac{\partial}{\partial y}\left(K_y \frac{\partial v}{\partial y}\right) + \tau_{wy} - \tau_{by}$$

where, t = time; x, y are Cartesian co-ordinates; u and v are depth averaged velocity components in the x and y directions, respectively; f = Coriolis parameter; g = acceleration due to gravity; Kx, Ky diffusion coefficients in the x and y directions, respectively; η = water elevation with respect to mean sea level, H = total water depth at any instant.

4.8.2.2 MODEL DESCRIPTION

Dedicated software Hydrodyn - FLOSOFT and Hydrodyn - POLSOFT for prediction of tides and currents and dispersion (pollutant transport) processes in the seas and estuaries developed at Environ Software (P) Ltd, Bangalore, were utilized for the studies.

The region of study is selected between geographical coordinates: Longitude of 292000E - 323000E and Latitude of 1894800N - 1931500N for carrying out sensitivity analysis and extended for predicting the flow regime due to the proposed intake and outfall in the domain. The model domain selected for the study is shown in Figure4.8.2 with the intake and outfall points. The calibration points TL (308441 E; 1915284N) and CM (308441 E; 1915284N) – points where the measurements for tides and currents were taken (Section-4.8) for the purpose of calibrating and validating the model.

The terrain features of the study domain for the model is given in Figure 4.8.2. The locations of the intake point and outfall of disposal points [CW (cold water) and HW (warm water)] are shown in Figure 4.8.3. The model domain is divided into FEM grid in 3D. Figure 4.8.4 shows the computational FEM grid for the domain in three dimensions. The bathymetry is selected from the measured hydrographic chart data and checked with the measured bathymetry data supplied. The interpolated bathymetric depth contours for the model are shown in Figure 4.8.5. From the figure, it can be seen that the maximum depth contour is 21 m in the domain.

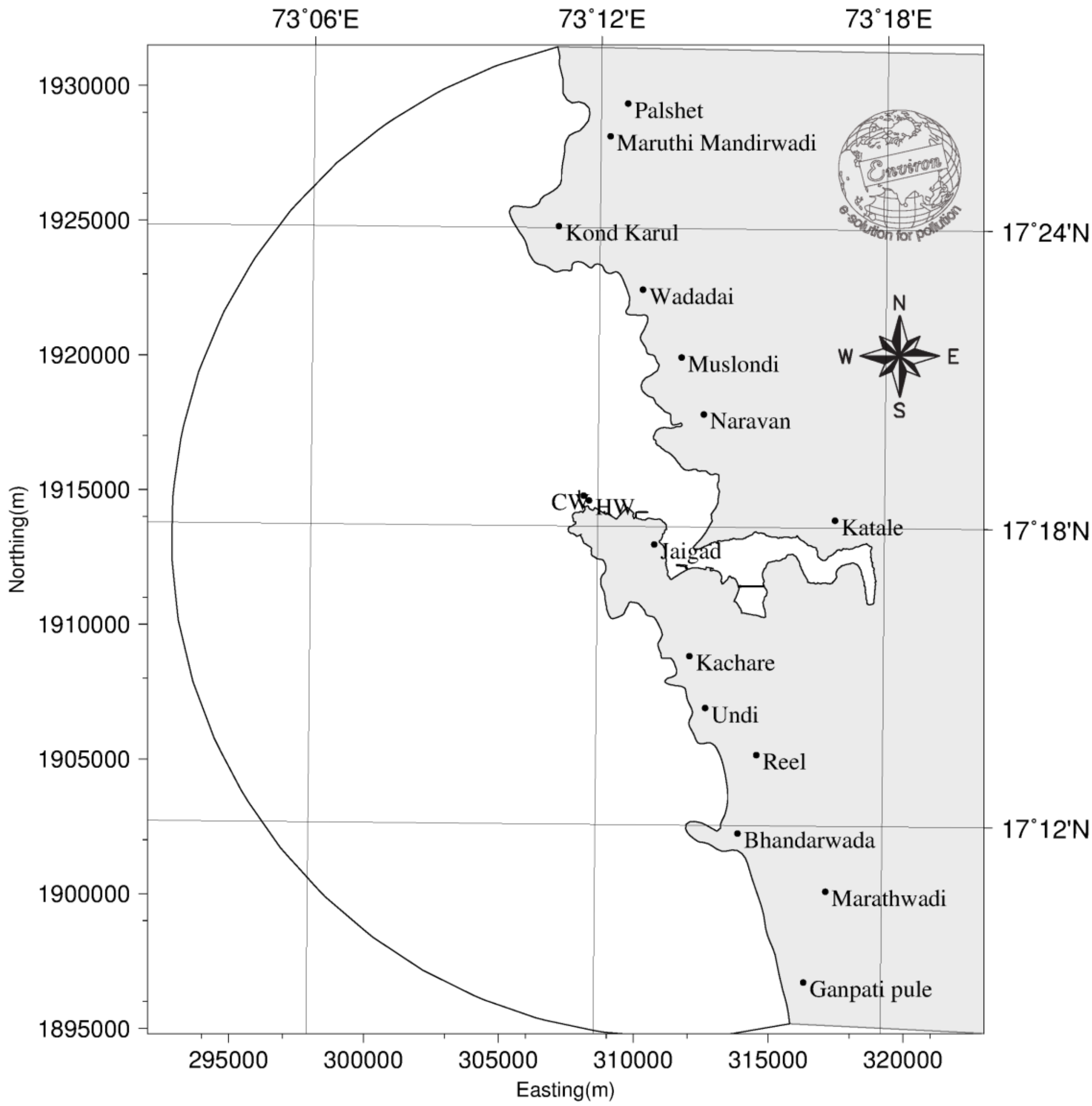


Figure 4.8.2: Showing the proposed location of outfalls (CW and HW) of LNG plant

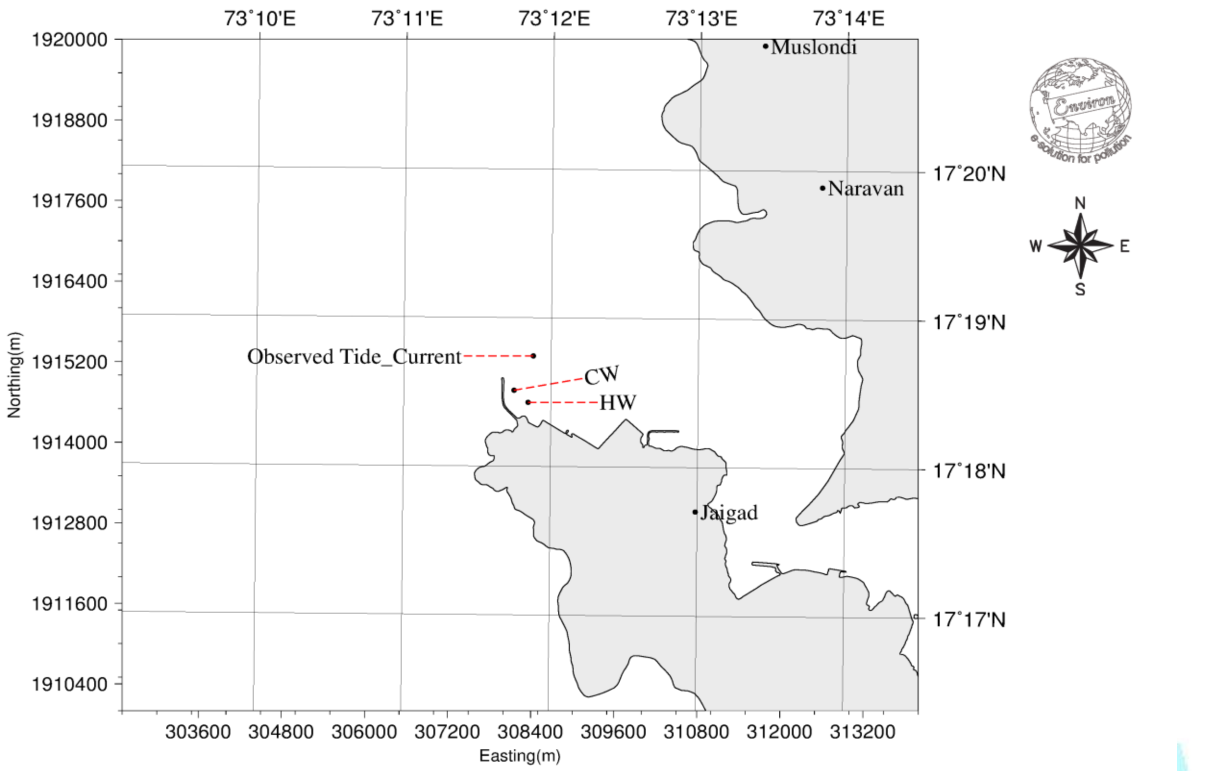


Figure 4.8.3: Showing the proposed location of outfall locations (CW and HW) of LNG plant and observed location of tide and current

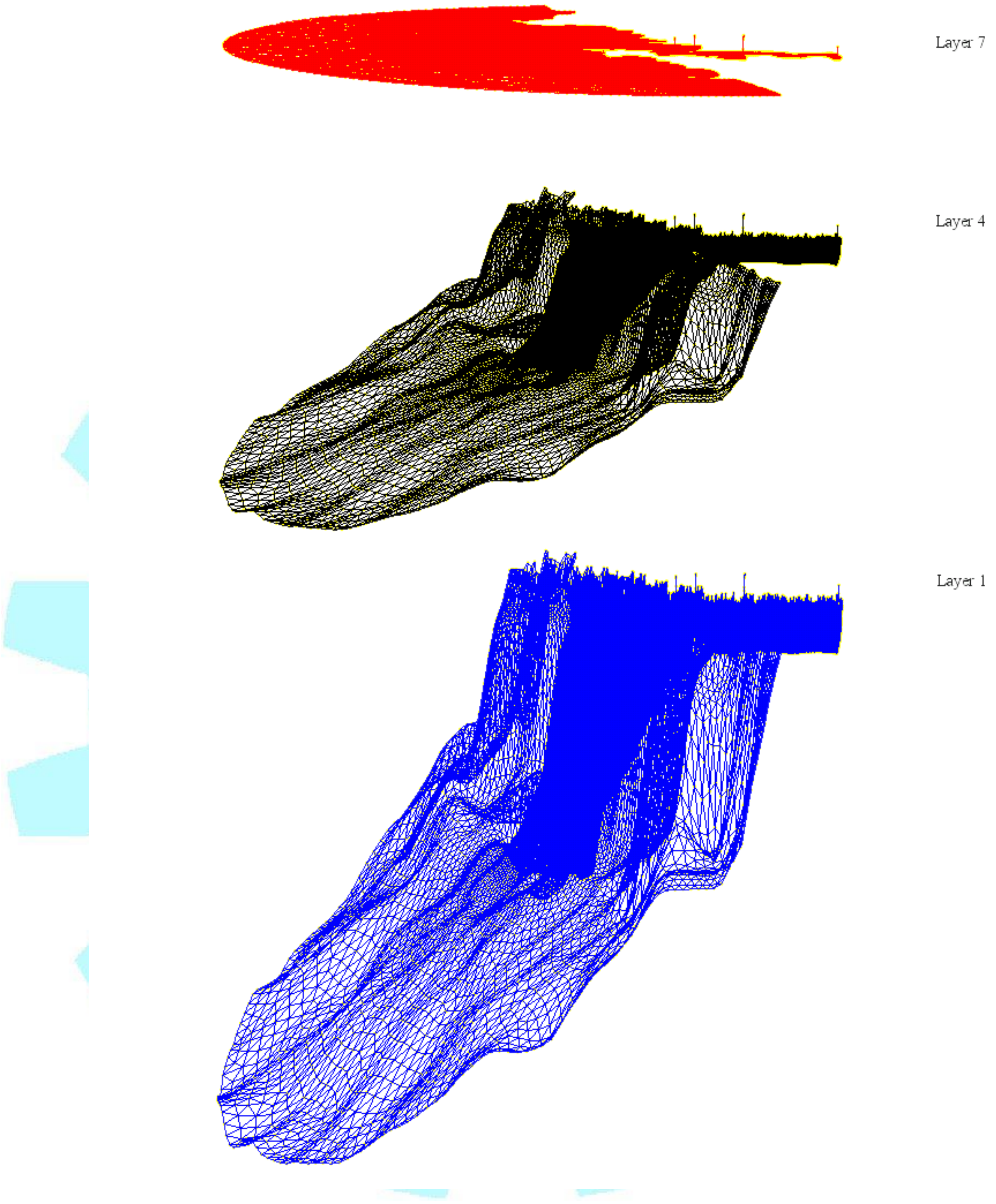


Figure 4.8.4: Computational mesh (Top, Middle and Bottom layers)

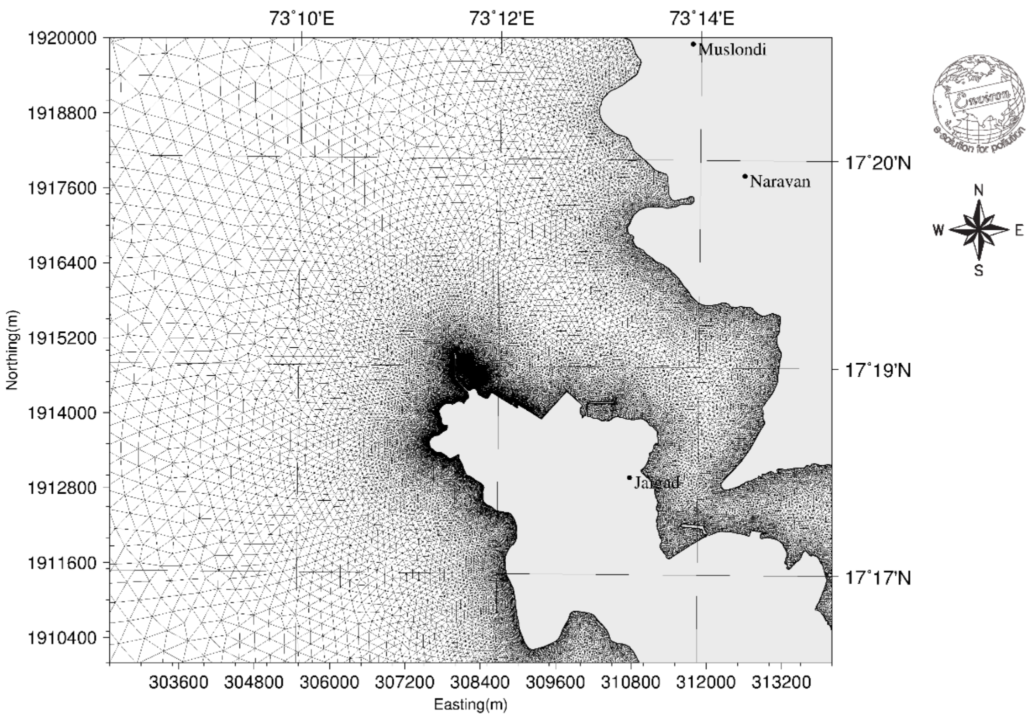


Figure 4.8.4 (a): Computational mesh (Top layer)

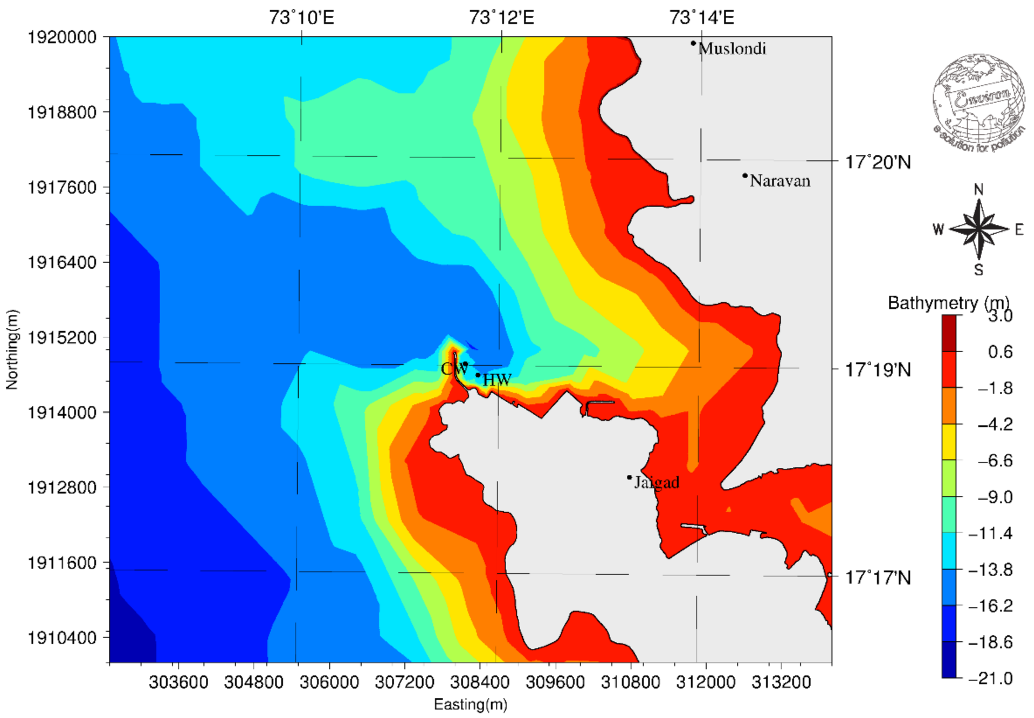


Figure 4.8.5: Interpolated Bathymetric Depths

4.8.2.3 MODEL CALIBRATION

Tide and current data from locations TL and CM (Section 4.7) were compared with the model simulated / computed results to check the variation and thus calibrate the model. The model gets validated when the computed and measured values match within the permissible variation allowed. The geographical location of these measurement stations/points are given in the table below:

Measurement Point	Latitude, N	Longitude, E	Measurements carriedout for
TL	19°15´28.4N	30°84´41 E	Tides
CM	19°15´28.4N	30°84°41 E	Currents

A comparison between the measured (observed) and computed tides and velocities is graphically shown in Figures 4.8.6 and 4.8.7 respectively. From these figures, it is evident that the values matched well (variation is less than <5%). Hence it can be considered that the model was validated and would produce the flow regime accurately for the tides and velocities in the study domain.

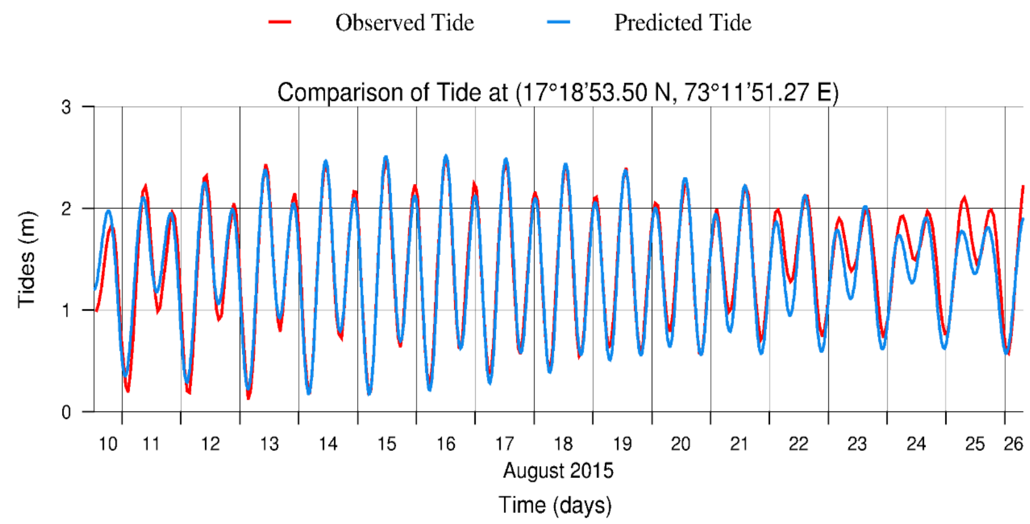


Figure 4.8.6: Comparison of computed and observed tides (Dec 2013)

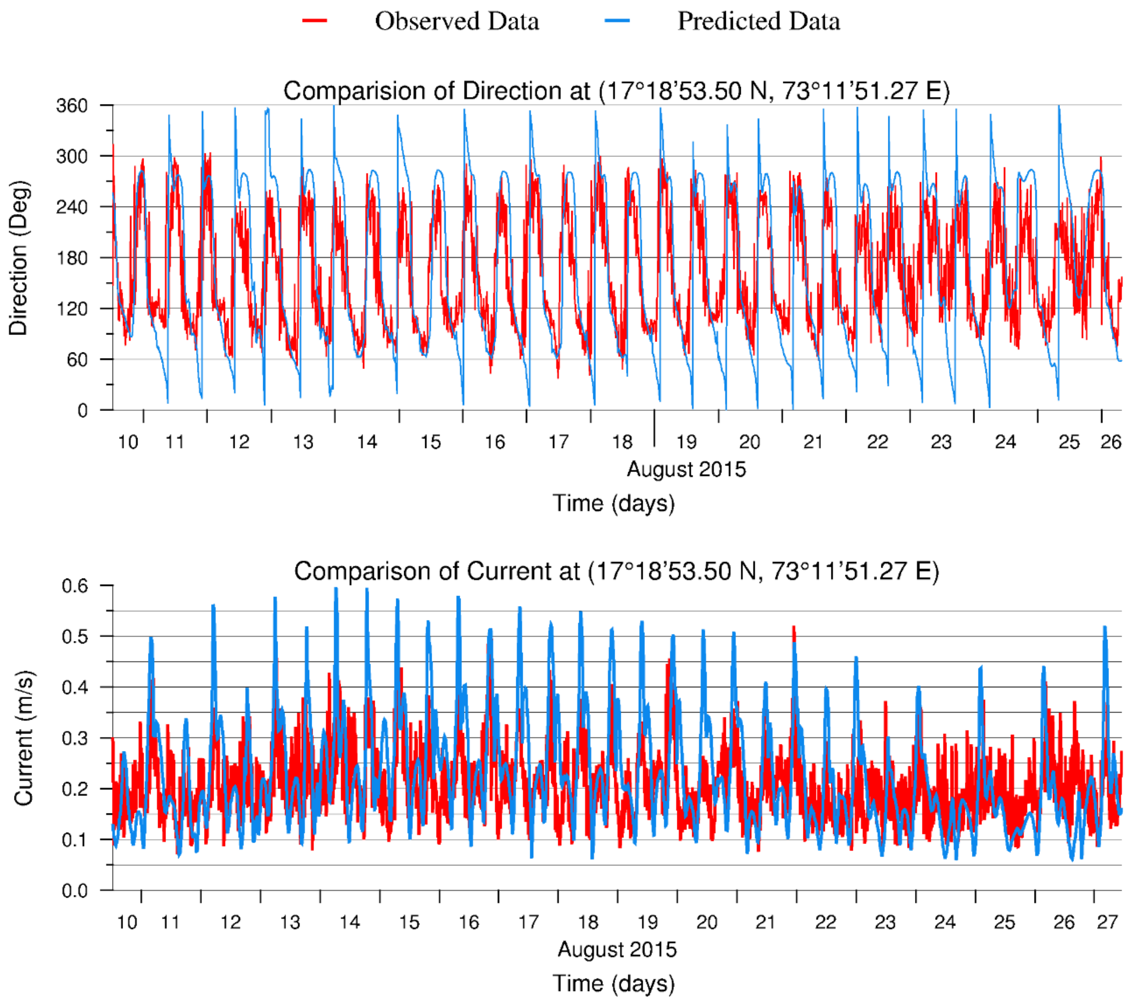


Figure 4.8.7: Comparison of computed and observed currents (August 2015)

The model runs were carried out for 15 days covering spring and neap tide conditions to understand the basic hydrodynamic behavior of the study domain. The typical tidal elevations and velocities for Lowest Low Water (LLW), Highest High Water (HHW), Peak Flood (PF) and Peak Ebb (PE) have been generated. A few representative scenarios are presented graphically in Figures 4.8.8 to 4.8.13.

Figures 4.8.8 and 4.8.9 which show the spatial variation of tides and currents during neap tide low water condition, the water level varies between 0.55 m and 0.61 m in the domain with the tide level of 0.57 at the proposed outfall locations. The flow velocity is in the range 0.0 m/s – 1.17 m/s with the predominant flow is in northward direction.

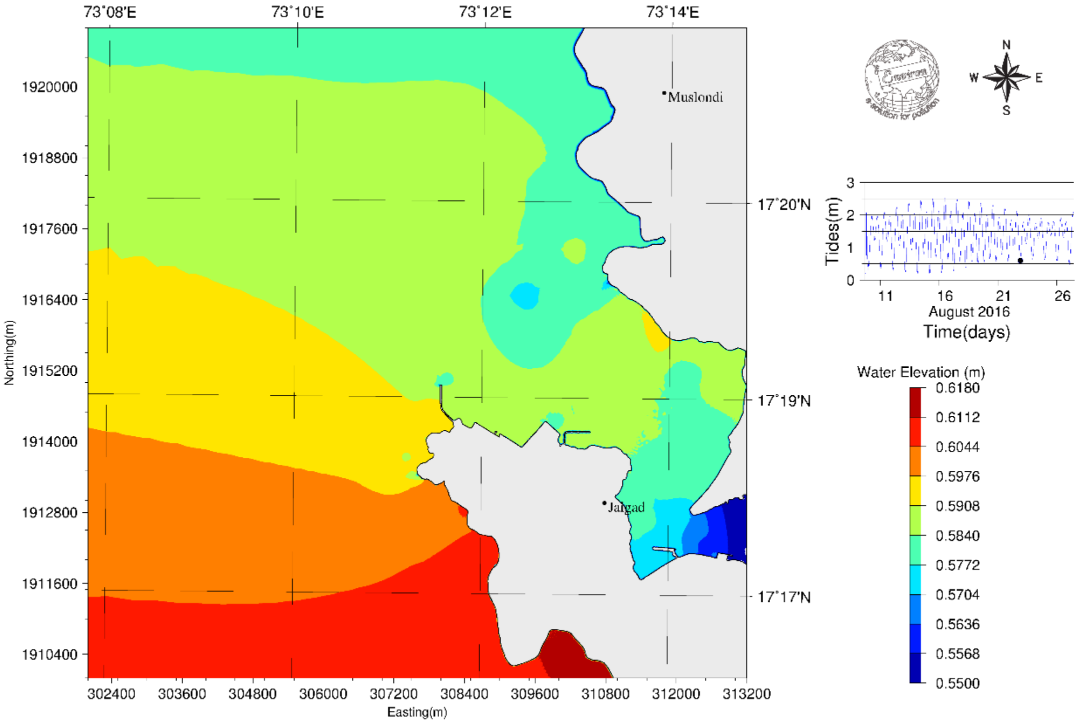


Figure 4.8.8: Simulated tides (at 2.8.2016; 21:30:00 h) during neap tide-(LLW)

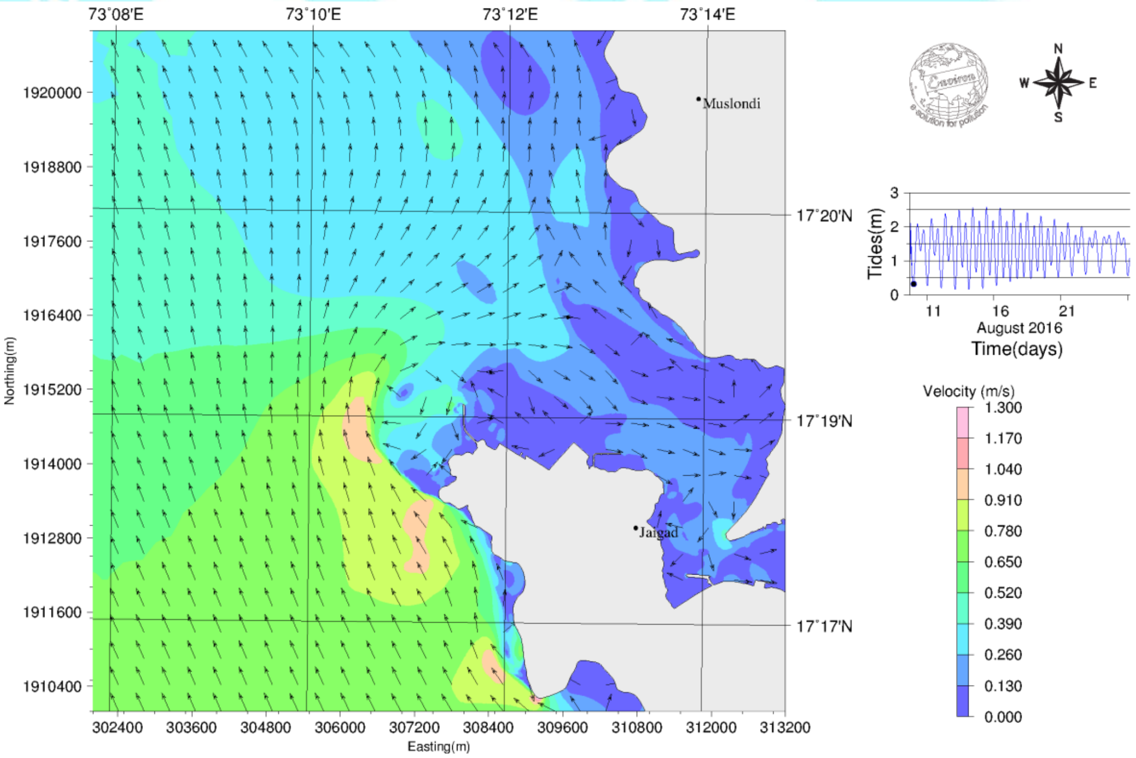


Figure 4.8.9: Simulated currents (at 2.8.2016; 21:30:00 h) during neap tide-(LLW)

During neap tide peak flood (Figures 4.8.10 and 4.8.11) the water level varies between 1.44 m and 1.54 m in the domain with the flow velocity in the range 0.1 – 0.7 m/sec in the north direction.

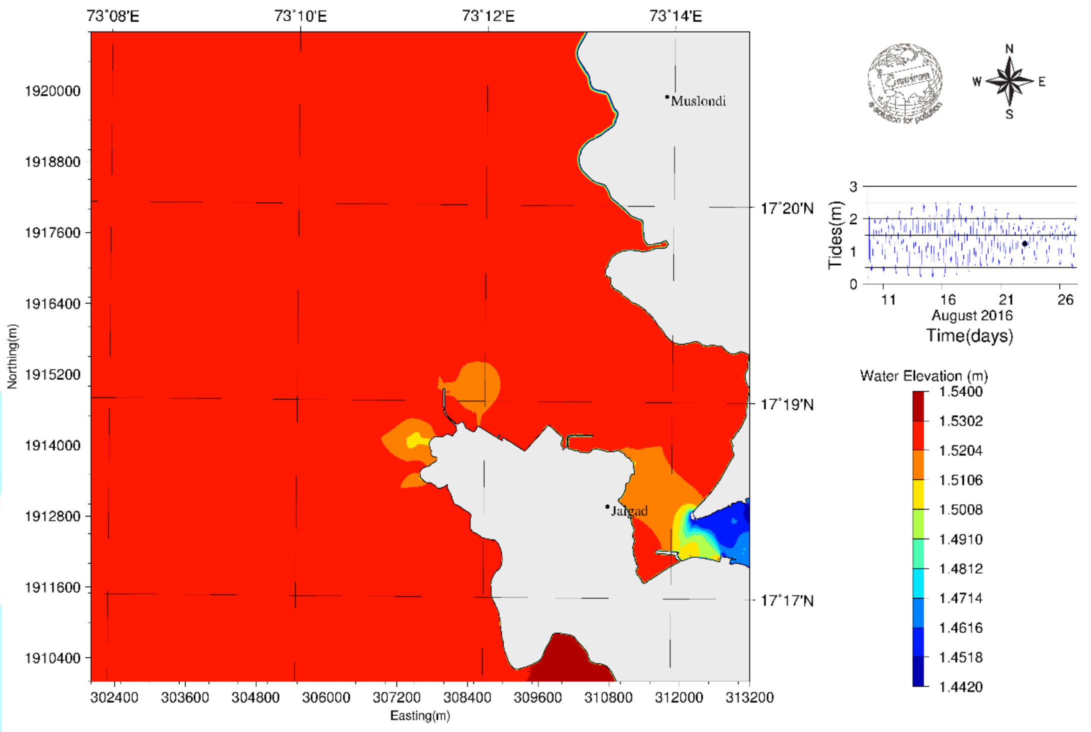


Figure 4.8.10: Simulated tides (at 23.8.2016; 00:30:00 h) during neap tide-(FLD)

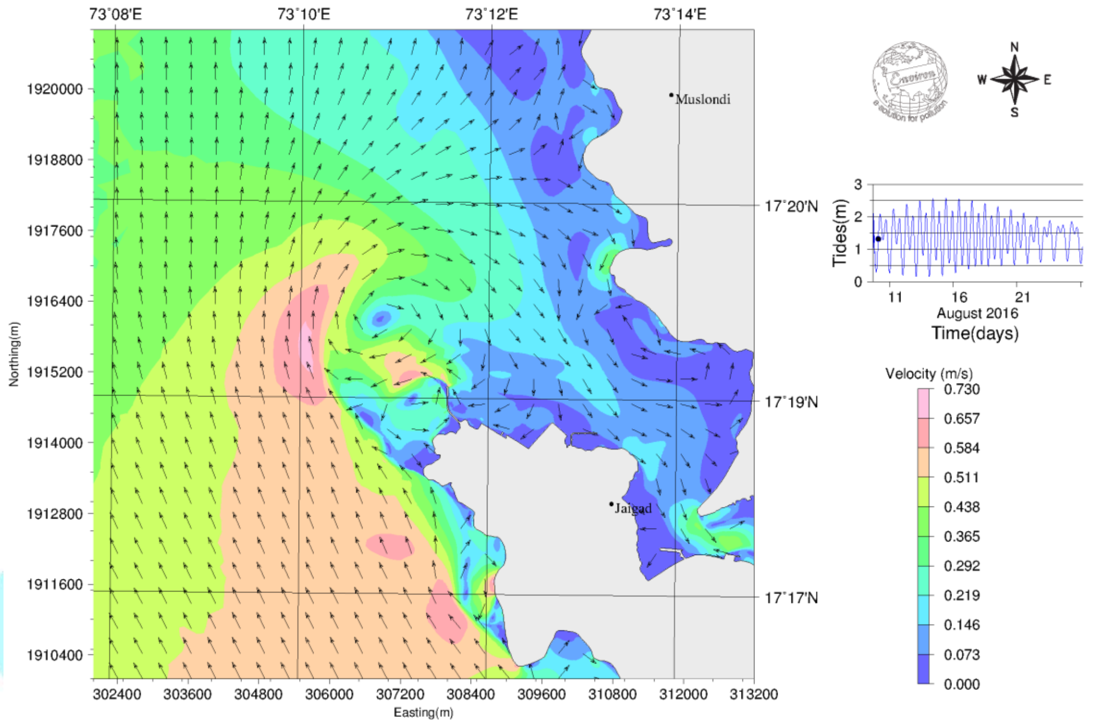


Figure 4.8.11: Simulated currents (at 23.8.2016; 00:30:00 hrs)during neap tide- (FLD)

Figures 4.8.12 and 4.8.13 illustrate the spatial variation of tides and currents during spring tide HHW condition. The water level varies between 3.34 m and 3.43 m in the domain and the flow velocity fluctuates from 0.01 m/sec to 1.4 m/s directed towards south at the outfall locations.

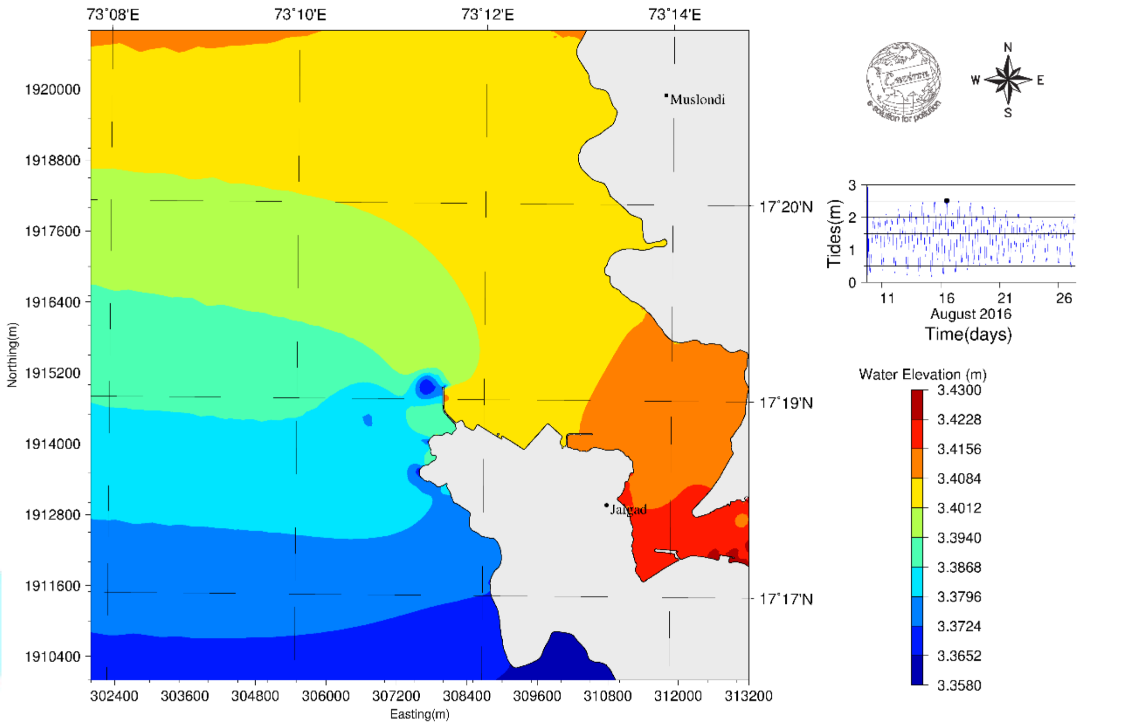


Figure 4.8.12: Simulated tides (at 6.8.2016; 12:15:00 h) during spring tide-(HHW)

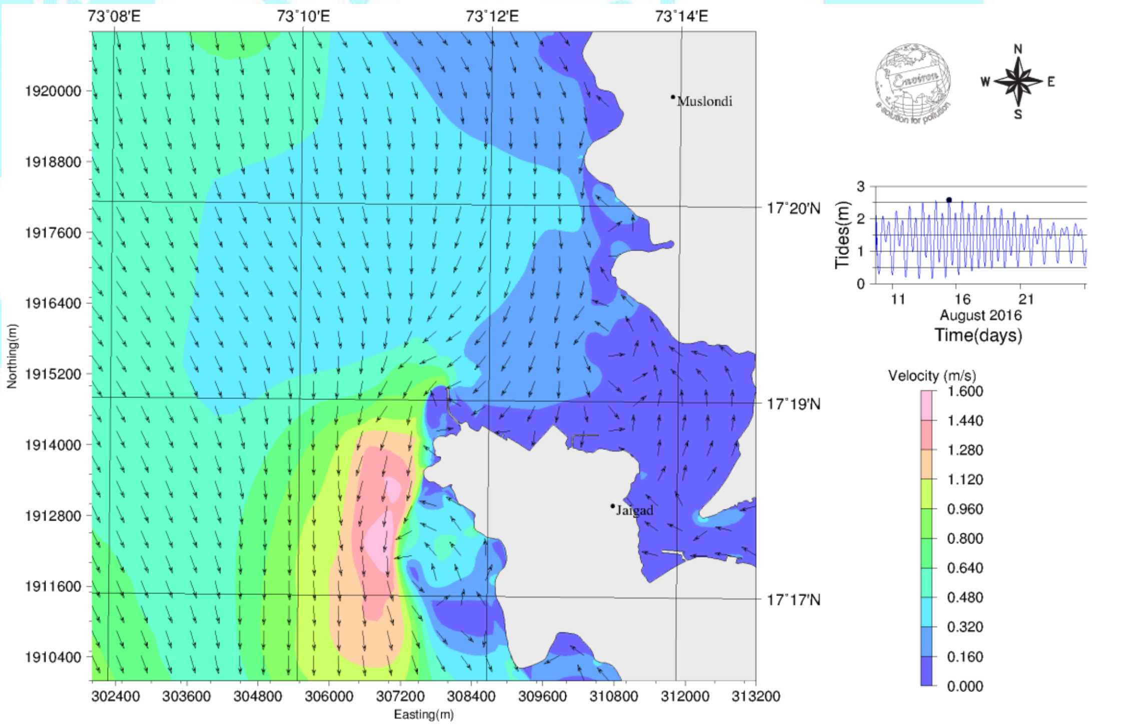


Figure 4.8.13: Simulated Currents (at 16.8.2016; 12:15:00 h) during Spring tide-(HHW)

4.8.3 MODELLING OUTFALL DISCHARGE

Numerical modelling studies were carried out to predict the extant of temperature changes due to dispersion compared to the ambient and predict the dilution that would be attained around the discharge location.

The water quality parameter considered for modelling studies is temperature 34.5º C for warm water discharge and 21.5º C for cold water discharge. Figures 4.8.14 and 4.8.15 show the proposed locations for outfall discharge of cold water and warm water.

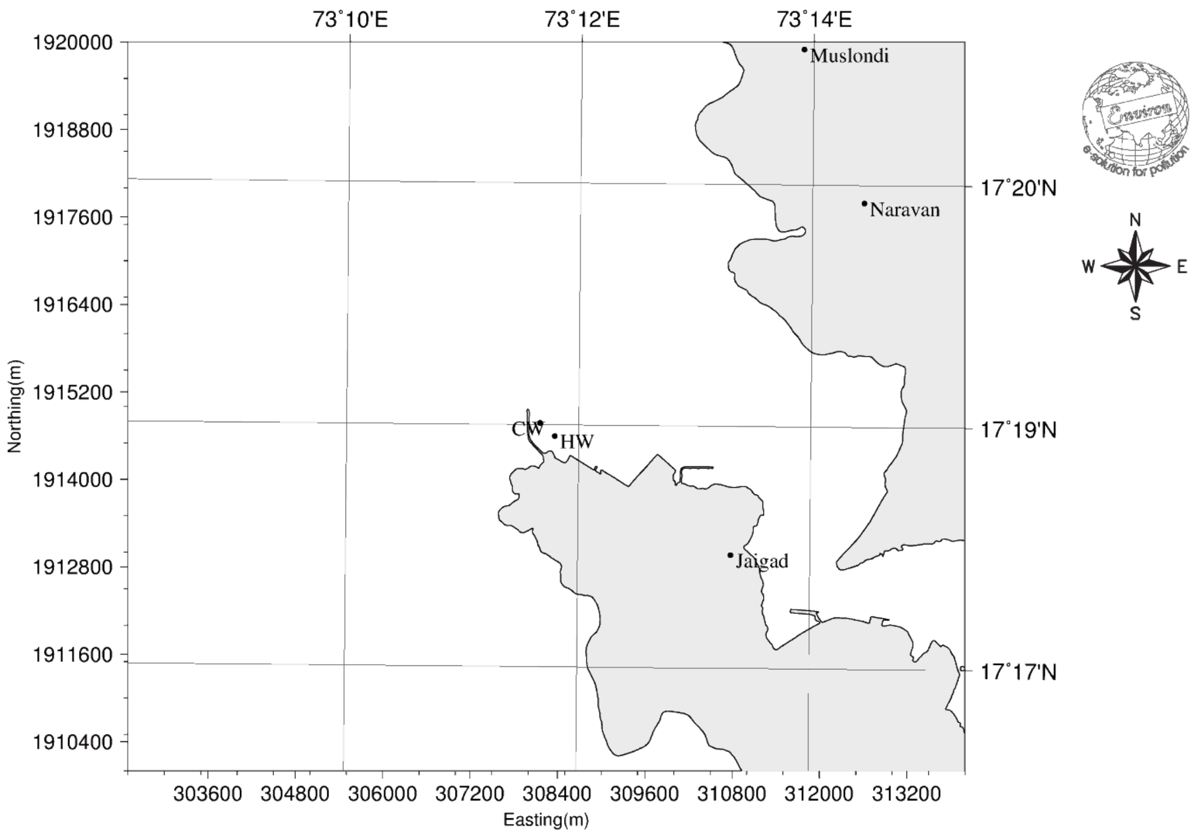


Figure 4.8.14: Locations of proposed outfall (cold water and warm Water)

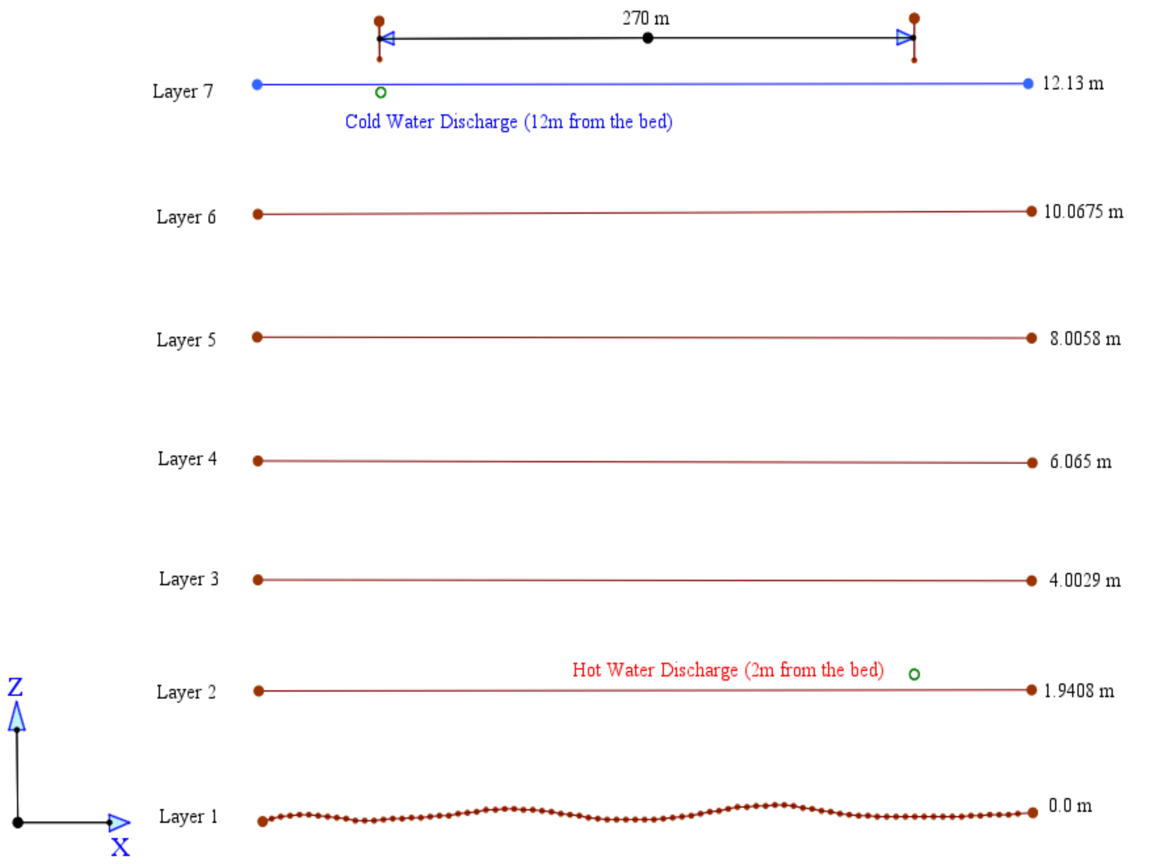


Figure 4.8.15: Locations of proposed outfall (cold water and warm water) in vertical grid

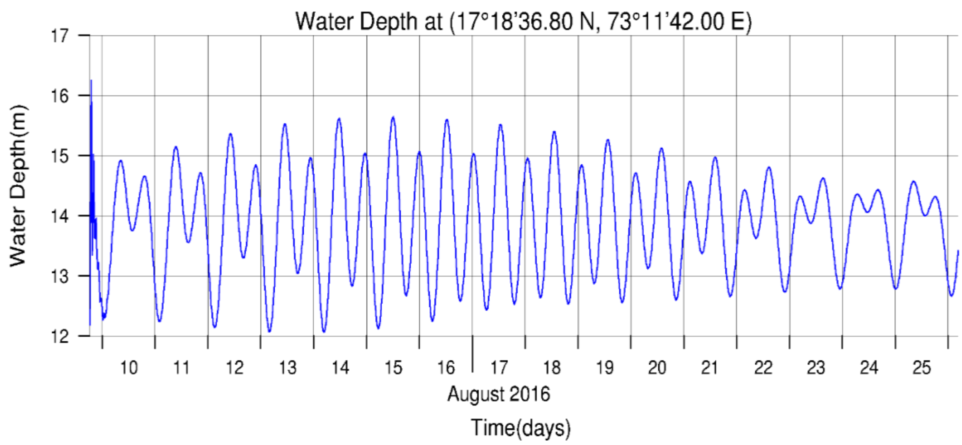


Figure 4.8.16: Variation of water depth at cold water outfall location

The outfall locations for discharge of return warm seawater is at coordinates (17°18’31.0” N; 73°11’48.9” E) and at level 2 m above the sea bed [Figure 4.8.17]. Likewise, the cold water site is at coordinates (17°18’36.8” N; 73°11’42.0” E) at depth of 12 m above the sea bed [(Figure 4.8.16)]. However, since these locations are integral to FSRU, the level of release of effluents would depend on the design of the FSRU. As discussed later, the water body at Jaigarh is vertically well-mixed the water column above the release sites would not be crucial though there is advantage for release of warm water effluent at depth to take advantage of density difference between the effluent and the ambient seawater. For modeling the level is considered at 2 m above the sea bed. Increasing the level to about 6 m above the bed would marginally affect the dispersion. Hence, in practice the location of release can be between 2-6 m above the sea bed. Similarly, the cold water release can be at any depth below the lowest low tide. For computational purposes this location is considered as 12 m above the sea bed.

The same model used for hydrodynamic modeling has been used for pollutant dispersion studies. The study domain is between Longitude of 292000 E - 323000 E and Latitude of 1894800N - 1931500N as shown in Figure 4.8.1 along with terrain features including outfall locations. Computation runs were made for the outfall locations to predict the changes in the flow regime and temperature considering the minimum as well as maximum values of outfall water temperature for a period of 15 days during spring and neap tide conditions.

4.8.3.1 MODELING OF WARM WATER DISCHARGE

The results pertaining to variation of temperature at and around the discharge point for spring tide condition are shown graphically in Figures 4.8.18 to 4.8.23 During spring tide at peak flood condition the dispersion is elongated towards the northwest with the central patch having a higher temperature but reached the ambient values within a distance of 50 m from the point of disposal.

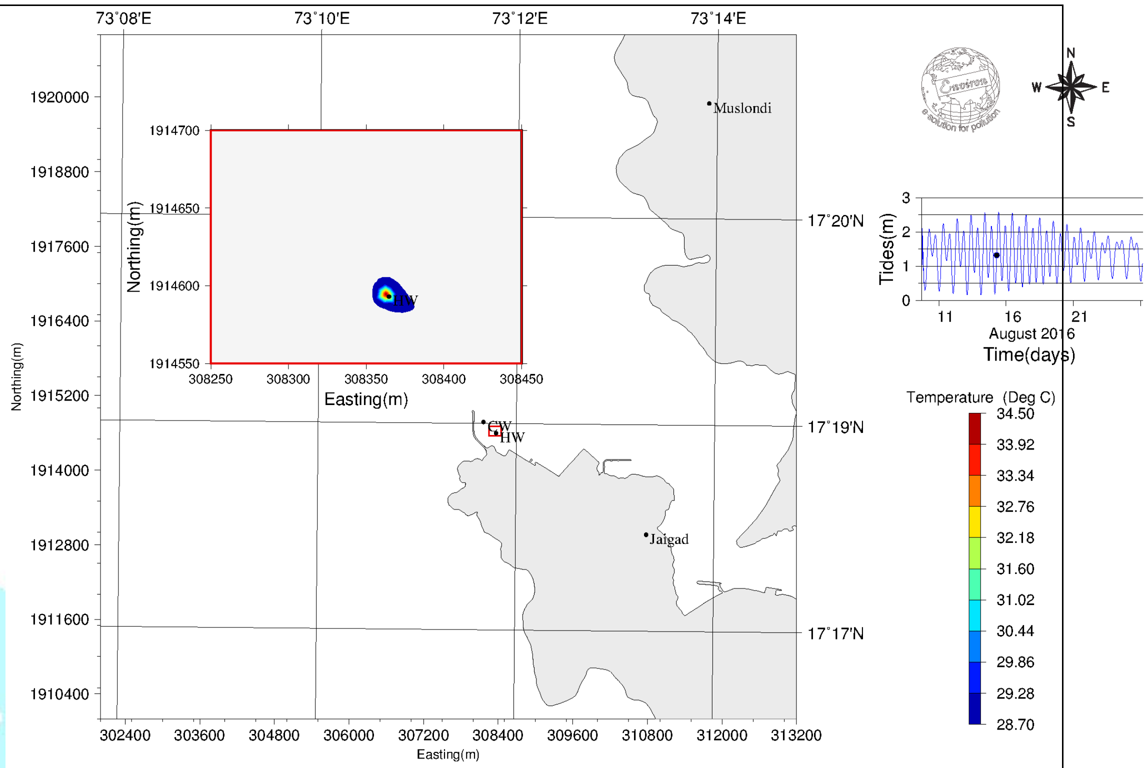


Figure 4.8.18: Hot water dispersion during spring tide - FLD(2nd layer)

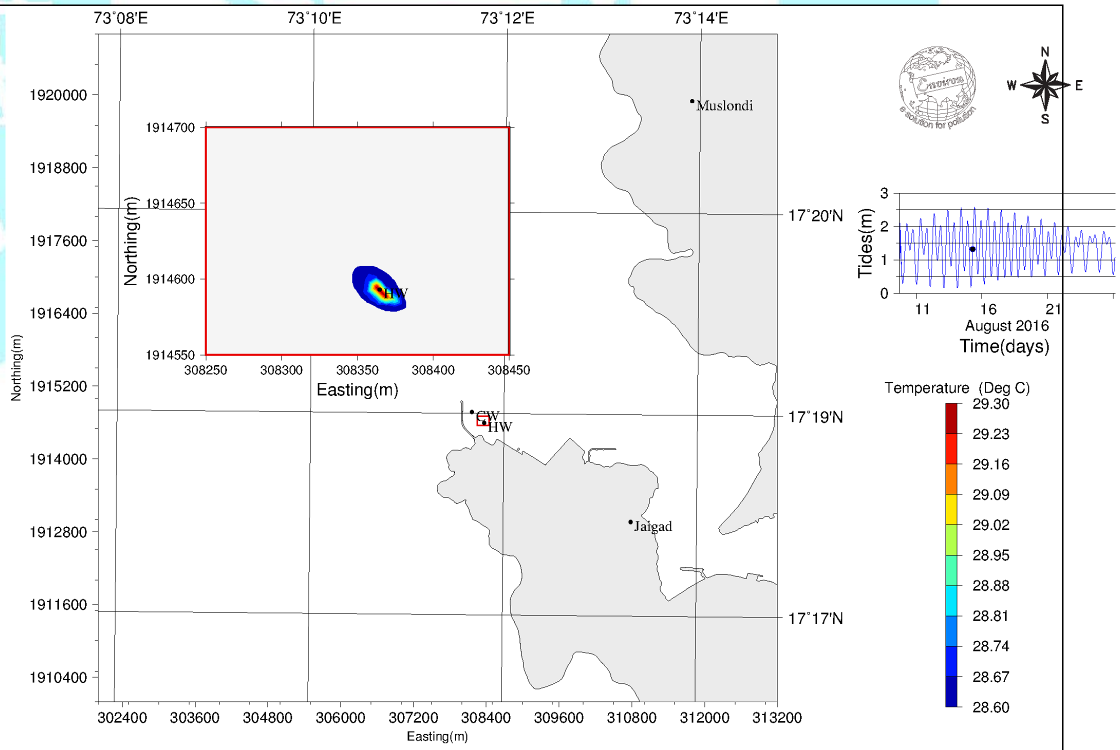


Figure 4.8.19: Hot water dispersion during spring tide - FLD(5th layer)

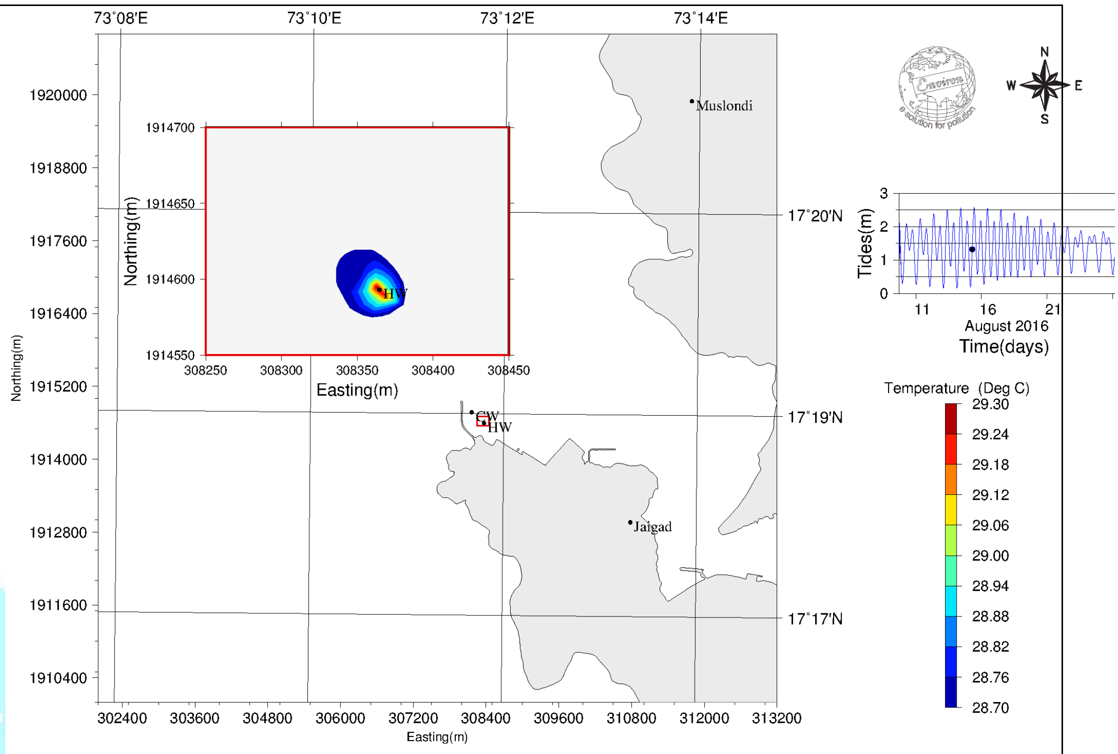


Figure 4.8.20: Hot water dispersion during spring tide - FLD(7^{th} layer)

Figure 4.8.21 to Figure 4.8.23 shows the dispersion of Temperature during spring tide peak ebb condition. The dispersion is more towards southeast from the outfall point and the central patch has a higher temperature. The ambient Temperature values are attained within a distance of 50 m from the point of disposal.

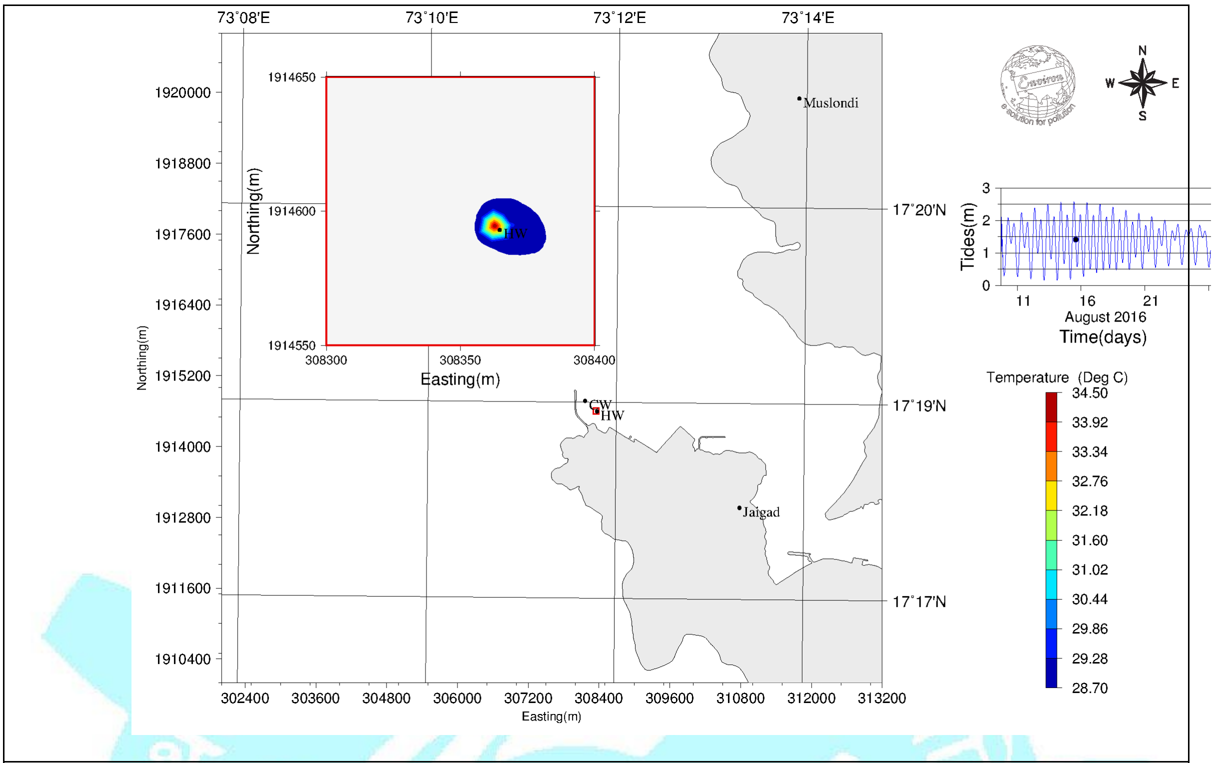


Figure 4.8.21: Hot water dispersion during spring tide - EBB(2nd layer)

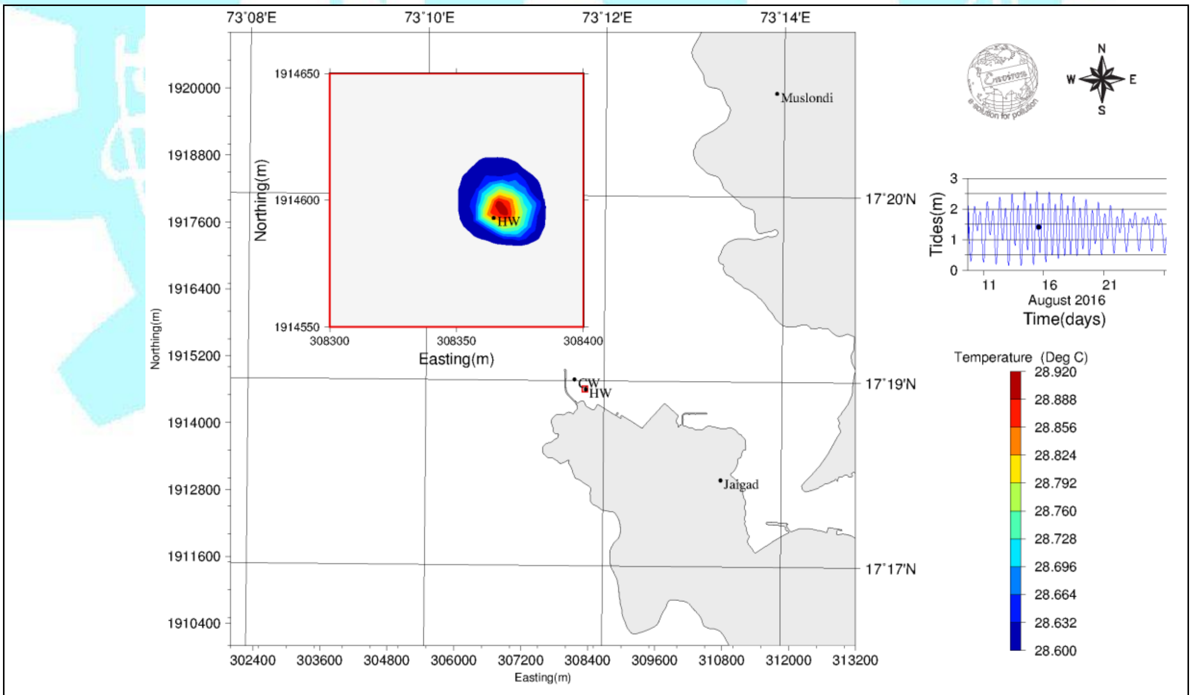


Figure 4.8.22: Hot water dispersion during spring tide - EBB(5th layer)

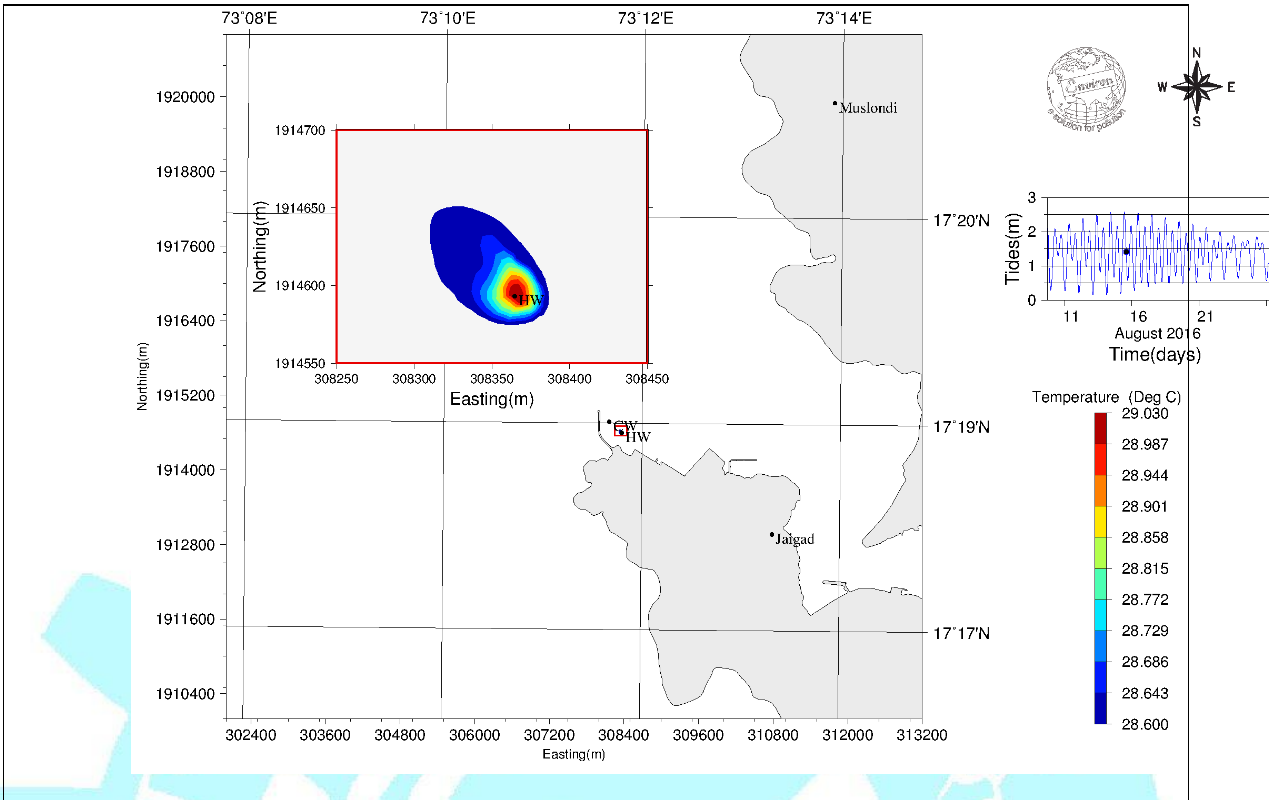


Figure 4.8.23: Hot water dispersion during spring tide - EBB(7th layer)

A number of observation points were selected around the outfall location (1 through 20) to measure and record the variation of temperature. The location of the observation points is shown graphically in Figure 4.8.24.

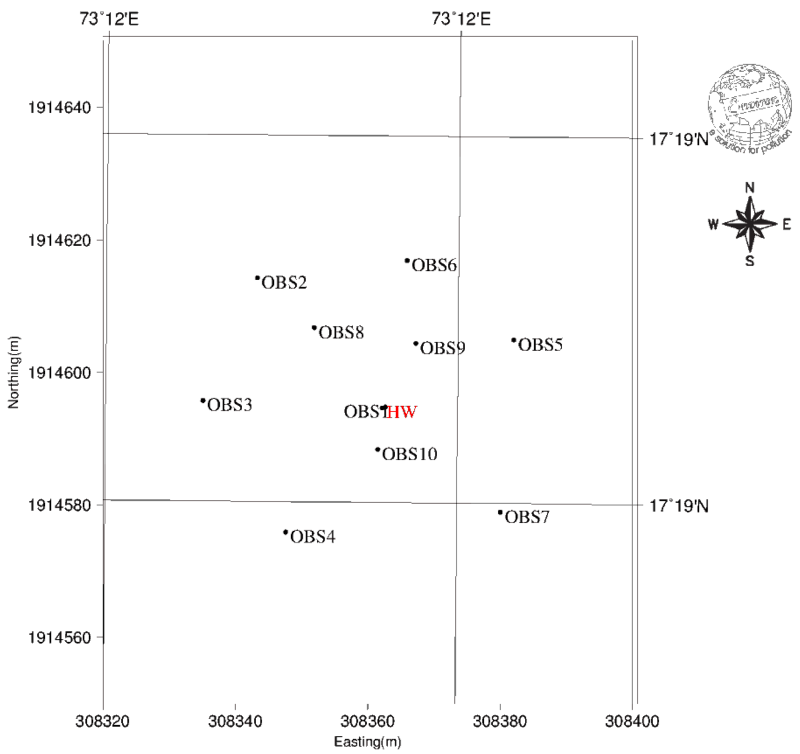


Figure 4.8.24: Observation points at and around outfall of warm water -7th layer (Topmost)

The variation of temperature at different locations (observation points) for the proposed outfall discharge is shown in Figure 4.8.25(a) and Figure 4.8.25(b). From the figures, it can be seen that the temperature dispersion at all tidal conditions is limited to a small area around the outfall discharge point.

The variation of the temperature inside the patch is predicted to be in the range of 28.5^0 C to 29.0^0 C during different tide conditions. From the figures, it can be concluded that there will not be any recirculation and there will be no impact on water quality at the shore due to high dispersal of the effluent.

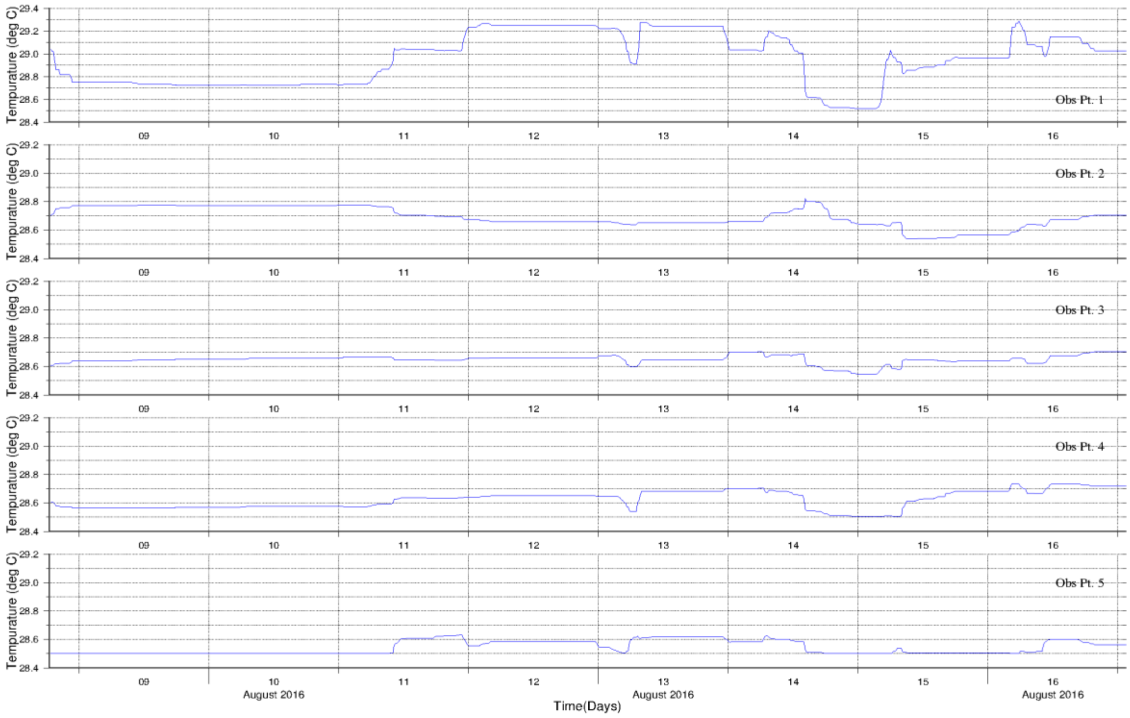


Figure 4.8.25(a): Variation of temperature at different observation points

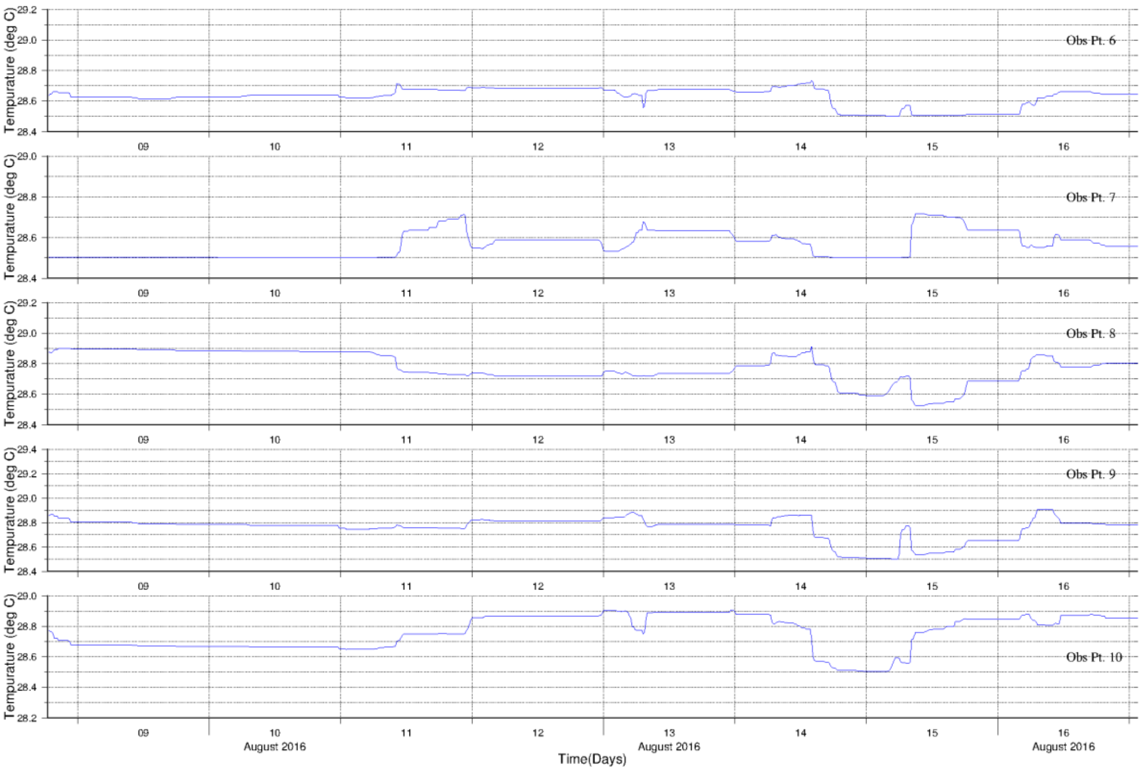


Figure 4.8.25(b): Variation of temperature at different observation points

Table 4.1 Variation of Temperature at the outfall (length of the dispersion from the outfall location and Extant (area) of dispersion.

HOT WATER										
Tidal condition	**Layer**	**Direction of plume dispersion**	**Dimension (l*b) m^2**	**Temperature (°C) at various Distance**						
				North-West				**South-East**		
				0	50	100	150	-50	-100	-150
Spring Peak Flood (PF)	2	NW & SE	40*30	33.92	28.5	28.5	28.5	28.5	28.5	28.5
	5		50*40	29.3	28.5	28.5	28.5	28.5	28.5	28.5
	7		50*50	29.3	28.5	28.5	28.5	28.5	28.5	28.5
Peak Ebb (PE)	2	NW & SE	30*25	33.34	28.5	28.5	28.5	28.5	28.5	28.5
	5		30*30	28.8	28.5	28.5	28.5	28.5	28.5	28.5
	7		69*67	29.03	28.6	28.5	28.5	28.5	28.5	28.5

The above table indicates that there will not be any signature of temperature rise beyond 50 m distance in any tidal condition.

4.8.3.2 MODELING OF COLD WATER DISCHARGE

From Figure4.8.26 to 4.8.28 it is evident that the dispersion is elongated towards northwest direction during spring tide with the central patch having lower temperature. The maximum temperature drop is predicted as 0.32°C in spring tide at 50 m distance from the point of disposal.

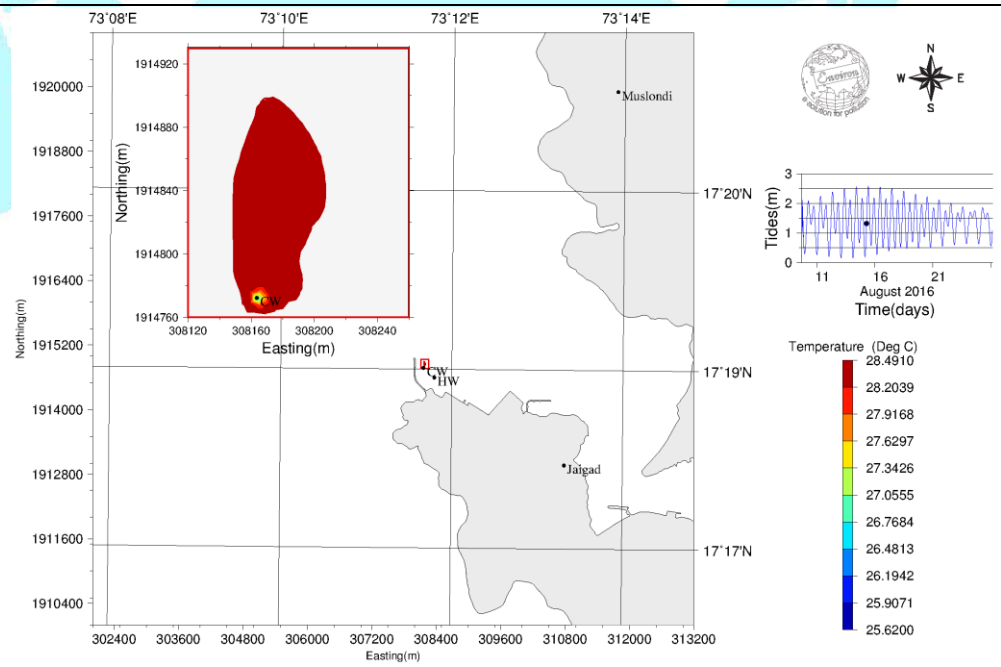


Figure4.8.26: Cold water dispersion during spring tide - FLD(7th layer)

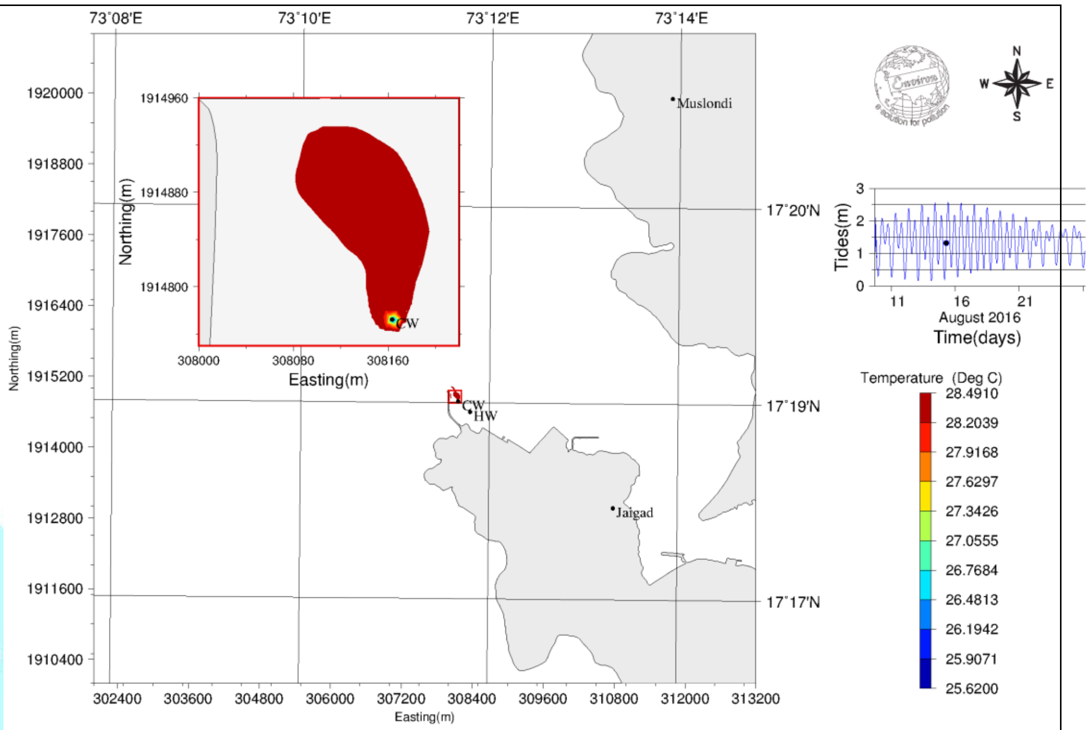


Figure 4.8.27: Cold water dispersion during spring tide - FLD(5th layer)

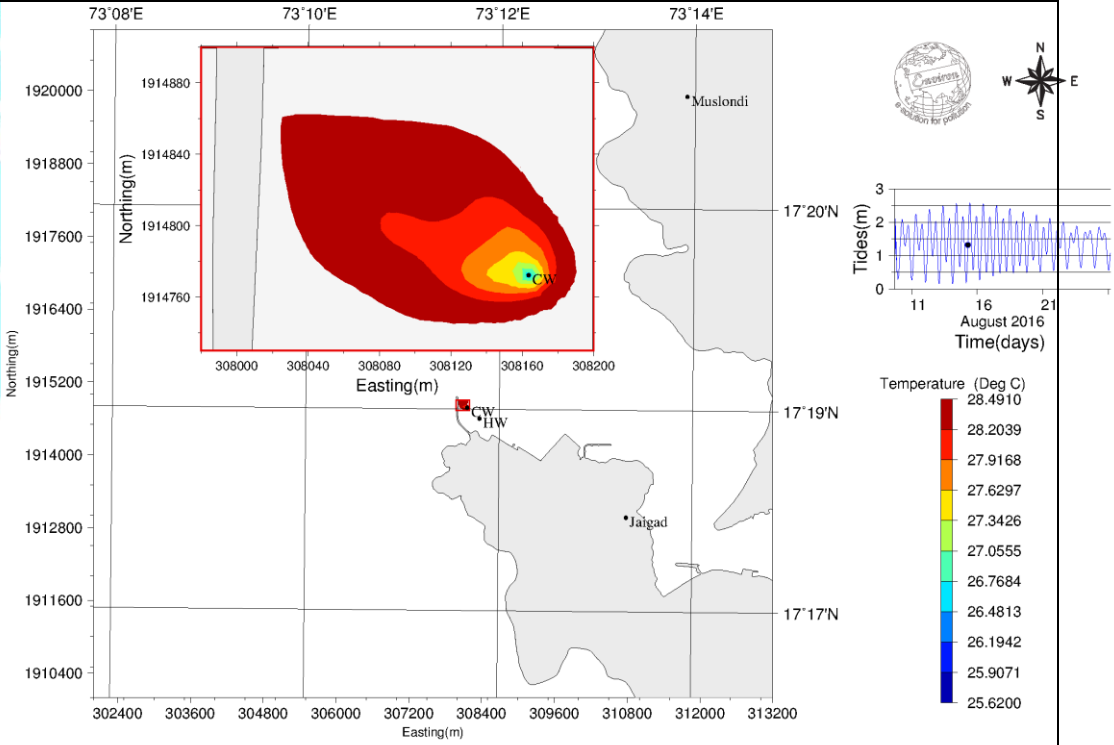


Figure 4.8.28: Cold water dispersion during spring tide - FLD(2nd layer)

A number of observation points have been put around the mouth of outfall (1 through 20) to measure and record the variation of Temperature. The location of the observation points is shown graphically in Figure 4.8.29.

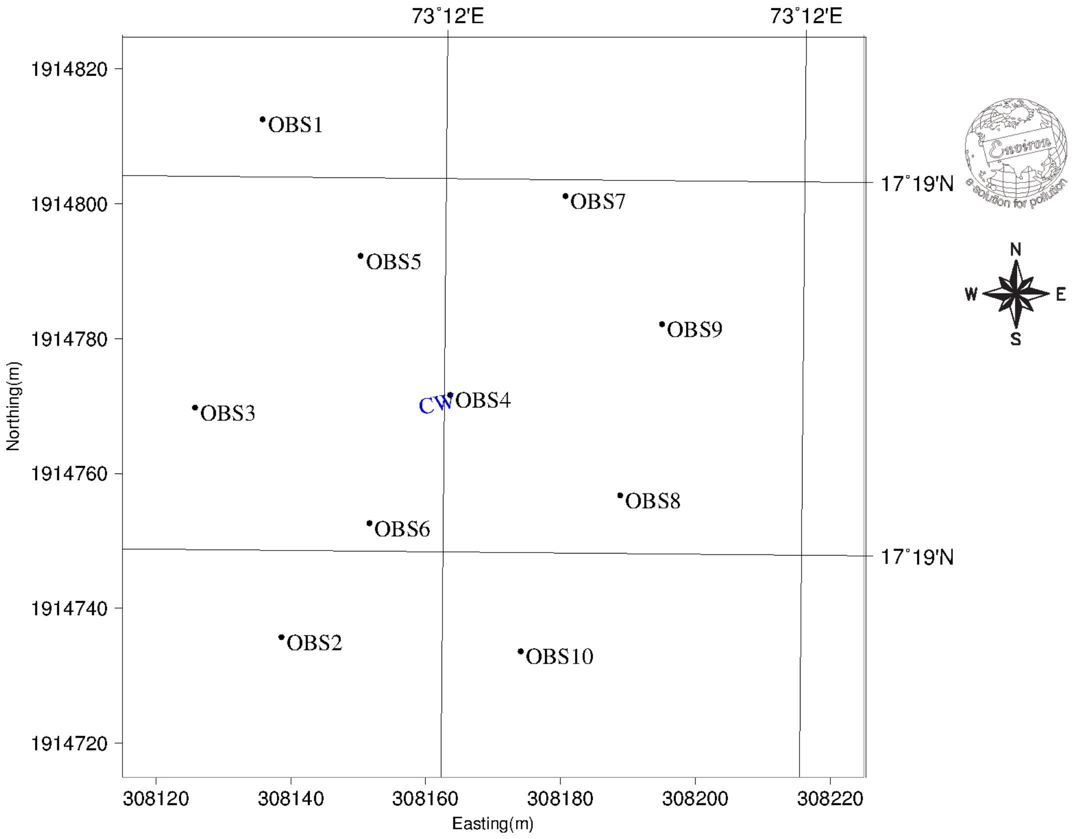


Figure 4.8.29: Observation points at and around outfall. (2nd layer)

The variation of Temperature at different locations (observation points) for the proposed outfall discharge is shown in Figure 4.8.30 (a) and Figure 4.8.30(b). From the figures, it can be seen that the temperature dispersion is limited to a small area around the outfall. The variation of the temperature inside the patch will be in the range of 28.5^0 C to 29^0 C during the different tide conditions. It is also evident that there will not be any recirculation and there will be no impact on water qualities at the shore.

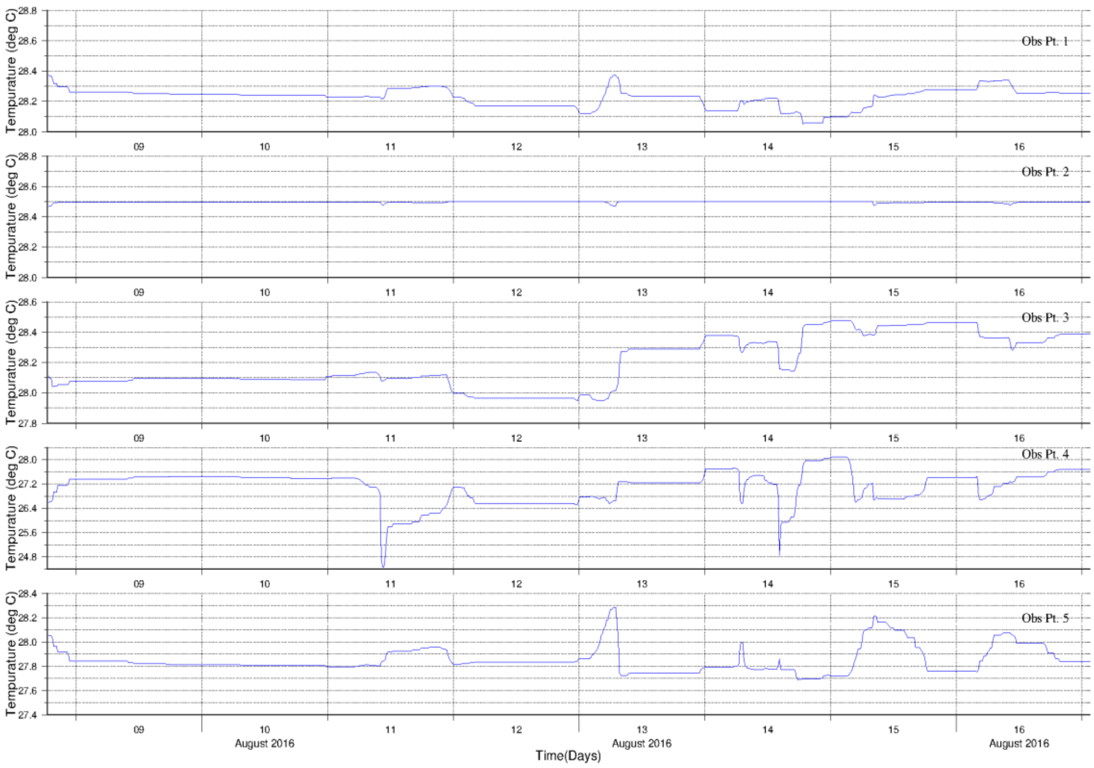


Figure 4.8.30(a): Variation of temperature at different observation points

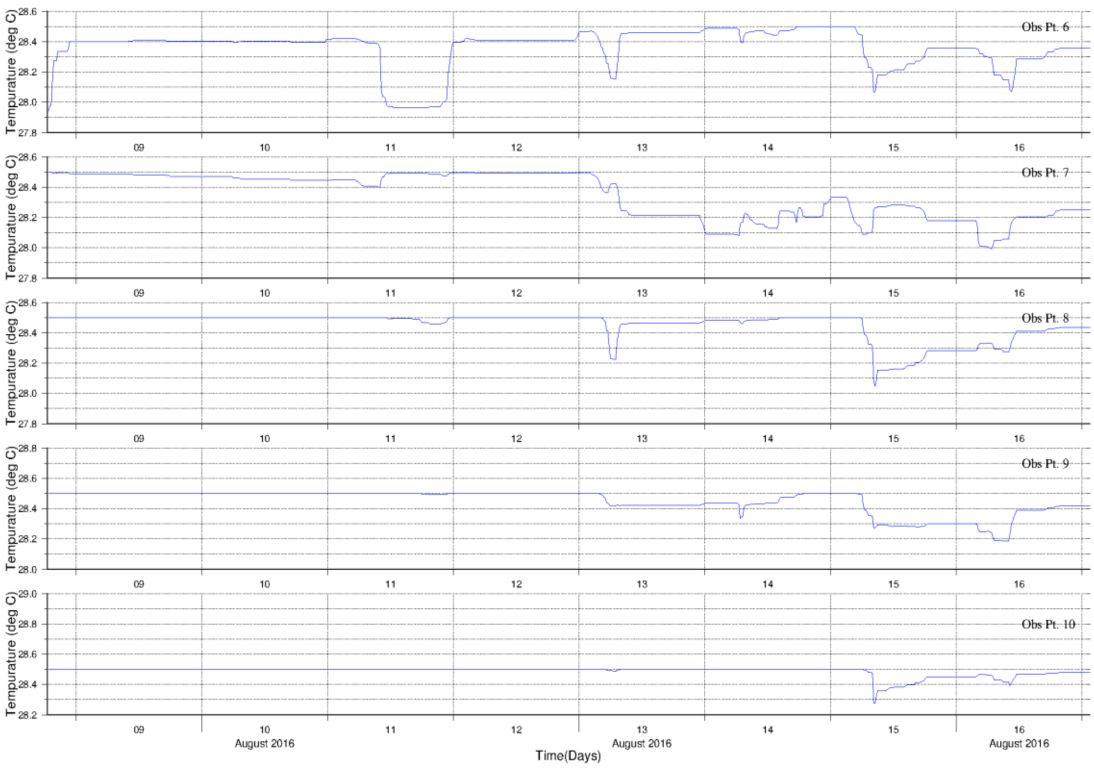


Figure 4.8.30(b): Variation of temperature at different observation points

Table 4.2: Variation of Temperature at the outfall location (length of the dispersion from the outfall location and Extant (area) of dispersion - when discharge of cold water temp is 7^0 C below ambient

COLD WATER										
Tidal condition	**Layer**	**Direction of plume dispersion**	**Dimension (l*b) m^2**	**Temperature (ºC) at various Distance**						
				North-West				**South-East**		
				0	50	100	150	-50	-100	-150
Spring										
Peak Flood (PF)	2	NW & SE	160*110	27.05	28.2	28.49	28.5	28.5	28.5	28.5
	5		80*150	27.34	28.49	28.5	28.5	28.5	28.5	28.5
	7		50*130	27.34	28.49	28.49	28.5	28.5	28.5	28.5
Peak Ebb (PE)	2	NW & SE	180*100	27.2	28.18	28.49	28.5	28.49	28.5	28.5
	5		40*70	26.01	28.49	28.5	28.5	28.5	28.5	28.5
	7		30*130	27.25	28.5	28.5	28.5	28.5	28.5	28.5

Thus it is evident from the above table that the maximum temperature drop is predicted as 0.32°C in spring tide at 50 m distance from above mentioned cool water outfall.

5 ANTICIPATED ENVIRONMENTAL IMPACTS & MITIGATION MEASURES

The probable project-related impacts on the environment during construction and operation phases are identified and suitable mitigation measures are discussed in this section.

5.1 IDENTIFICATION OF IMPACT / GENERAL

The development of offshore LNG FSRU at JSW Jaigarh Port involves various marine side and limited land side construction and operational activities. The overall operations of the proposed FSRU based LNG terminal fall into relatively low air polluting category, as the fuel requirement at the project site will be met from Boil Off gases (BOG) from LNG storage at the FSRU. The terminal shall be designed to include all of the utility systems necessary to support the processing facilities and the site infrastructure and buildings. Facilities like service water supply, storage and distribution, potable water supply, storage and distribution will be provided. The terminal will have sewage collection, storage, treatment and disposal and oily waste and aqueous effluent collection, storage, treatment and disposal facility.

The proposed development on land and marine side is within the existing port limit of JSW Jaigarh Port. Land under proposed development is barren & uncultivated, acquired & aggregated by JSW Group. The land is within the Port Boundary and designated for industrial use. Land shall be leased to HEGPL by JSWJPL. The terrain is rocky & hilly but generally flat with elevation between 32 and 38 m above the MSL and falls under zone –IV (moderate) seismic zone. The land for Phase I has been secured from JSWPL under a Deed of Lease cum Agreement to Sell. Land for Phase II of the project shall be made available by JSW under a specific land agreement.

5.2 LAND ENVIRONMENT

5.2.1 POTENTIAL IMPACT DUE TO LOCATION

The majority of activities of proposed FSRU such as LNG unloading, storage, handling and regasification will be carried out at offshore at the depth contour of 19 m. Thus requirement of land for the FRSU operations is very limited and activities to be carried out onshore receiving facility are metering, pig receiver etc. the regasified pipeline shall be connected to the nearest GAIL’s Panvel-Dahbol pipeline through a 60 km connection.

The proposed development on landside and marine side is within the existing port limit of JSWPL. There is no human habitation in the development area since the proposed site comprises largely reclaimed land for which the EC has been granted by MoEF&CC. Hence, there will be no direct PAPs (Project

Affected Persons) / PAFs (Project Affected Families) due to this project and Resettlement and Rehabilitation (R&R) is not envisaged.

5.2.2 IMPACTS DUE TO CHANGES IN LAND USE PATTERN

- FSRU which is essentially a LNG Carrier ship with high pressure pumps and vaporization and gas send out facilities installed, will be moored at the LNG jetty at the fully developed LNG berth in the Jaigarh port.
- While the waterfront structures will remain identical, the land based structures will be reduced considerably in Phase-I, since the regasification and the storage unit will be located on the FSRU.Jaigarh FSRU being a floating self-contained facility, it will not require on-land support except for the metering and control systems.
- Evidently, the changes in the land use pattern will be insignificant in Phase-I of the proposed project.

5.2.3 PROJECT SITE SPECIFIC IMPACTS

- The estimated land requirement of 10 acres for construction of onshore terminal / gas metering station is very limited since the major part of project (LNG storage and re-gasification) will be offshore.
- Private land procurement for the project will not be required. Hence, there will be no direct PAPs / PAFs due to this project, hence, R&R is not required.
- The project is barren and uncultivated with sparse casuarina plantation and there is no agriculture or any other activity at the site and in the immediate vicinity. This land is within port area and expected to be used for port based activities. Therefore, there will be no change in designated land use due to proposed project.
- Since project site is vacant land with sparse vegetation and does not have any significant natural vegetation / large trees or any conserved species, the site grading / preparation will not involve cutting of trees. The ORF site is revenue land and does not include any forest land.
- The existing fishery harbour is at a distance of about 6 km from the location identified for proposed LNG jetty. The route of fishing boats is entirely different / away from the project site and the navigation channel of ships. Hence, there wouldn’t be any hindrance to fishing and other vessels and their movements due the proposed project.

5.2.4 MITIGATION MEASURES

Mitigation measures or management controls to be applied are identified to eliminate or minimize adverse impacts. Mitigation measures include those that can be incorporated in the design phase, and are implemented during the construction and operation phases.

- Project proponent shall have necessary / appropriate coordination with the existing JSWP operator, as well as the neighbouring fishing harbour users for suitable planning and execution of proposed project to mitigate potential unforeseen adverse impacts, if any, on existing operations.
- CRZ clearance has been granted for the land and port extension from MoEF & CC, New Delhi.

Table 5.1: Significance of impacts

Criteria	**Significance Definition**	Level of Significance (H/M/L/I)
	No disturbance to the ecosystem or significant positive impact.	I
Compliance	Continuous non-compliance with national regulations, international standards, industry or corporate standard (e.g. exceedance of Environmental Quality Standard).	H
	Potential for non-compliance with national regulations, international standards, industry standards or corporate standard.	M
	In compliance at all times, or no regulations or standards apply	L
Ecosystem	Disturbance of a sufficient portion of the bio-geographic population of animal species to cause a change in abundance, distribution or size of genetic pool such that natural recruitment would not return the population of the species, and other species dependent on it, to former levels within several generations.	H
	Disturbance of a population or individuals of a species resulting in a change of abundance over one or more generations, but that does not change the integrity of the population of the species or populations of other dependent species	M
	Disturbance to individuals of a species that is similar in effect to the random changes in population due to normal environmental variation, or change resulting in positive, desirable or beneficial effects on an ecosystem.	L

Socio-Economic	Long-term interference to other users of resources. Change to demographics, employment, social service provision or lifestyle that is out of line with international guidelines or national policy affecting a large number of people and lasting considerably beyond programme lifetime. Activity that raises issues of major concern to stakeholders or may seriously damage a site of cultural importance.	H
	Short-term interference to other users of resources. Change to demographics, employment, social service provision or lifestyle that may affect groups of local stakeholders during the project. Activity that raises issues of some concern to stakeholders or cause minor damage to site with cultural importance.	M
	Temporary interference may be noticed by other users of resources that. Changes to demographics, employment, social service provision or lifestyle to which the authorities and local stakeholders are neutral; or beneficial changes to the well being of stakeholders.	L
	No interference may be noticed by other users of resources that changes demographics, employment, social service provision or lifestyle to which the authorities and local stakeholders are neutral; or beneficial changes to the well-being of stakeholders.	I
Health	Planned activity directly linked to increased mortality/morbidity or to widespread permanent disablement or reduction in wellbeing. Large number of people exposed or affected.	H
	Planned activity resulting in sustained increase in incidence of chronic illness (e.g. respiratory problems) in the local community. Requirement for increased healthcare expenditure. The affected population is predominantly vulnerable groups (disabled, low caste immigrant workers, women, children, aged). Planned activity resulting in complaints, litigation or fines.	M
	Incidence of chronic and short-term illness stays within previous levels or is reduced. Negligible change in community wellbeing.	L

H = High Significance, M = Medium Significance, L = Low Significance, I = Insignificant very temporary and local in nature

5.2.5 IMPACT DUE TO FSRU

Construction phase

The FSRU has been selected as the preferred option for the Early Production Facilities as virtually all the facilities are provided on the leased vessel. The FSRU is essentially a Conventional LNG Carrier with additional LNG vaporisation and send-out facilities installed on the main deck. The FSRU shall use the same facility created for the FSRU vessel, both in appearance, design and operations, remains a marine vessel and will be moored in place for the lifetime of the Project, except for departure under emergency conditions such as a tropical cyclone or for dry dock maintenance. FSRU being a floating self-contained facility, it will require limited on-land support except as described earlier in Section 2. Since, there is no specific construction work involved on project site for FSRU, there will not be significant negative impact of FSRU.

5.2.6 PROJECT COMMISSIONING PHASE

The commissioning phase of FSRU involves the following activities:

- Deployment of Pilot & tugs to berth the FSRU at the jetty.
- Commissioning of FSRU (on board LNG storage and regasification equipment), high pressure gas loading arms (on jetty platform), gas receiving facilities at ORF etc.
- Testing of safety systems including vents, emergency shutdown systems etc.
  All equipment and systems on-board the FSRU will be integrity tested before it is mobilized (with start-up LNG cargo), and all new pipe-works at the project site will be pressure tested. To start with, FSRU-jetty interfaces (loading arm, control & mooring systems) will be checked.
- The most significant impact on the sea water quality would be due to discharge of cold water in the event of selection of open loop regasification. In commissioning phase the discharge volumes will be relatively less and for limited time period. Due to the small quantities of discharge associated with the commissioning phase, potential impacts on the marine environment are expected to be of low significance.

5.2.6.1 POTENTIAL IMPACT DURING OPERATION

5.2.6.2 IMPACT DUE TO SEAWATER INTAKE

The proposed project is expected to pump around 17000 m^3/h sea water for regasification of LNG and cooling of machinery in the event of the open loop vaporisation system. The impact associated with the intake is due to Impingement, entrapment and entrainment of marine organisms. The volume of seawater intake and the cooled seawater discharge including the associated antifoulants in the effluent has the potential to impact juvenile fish. In the event that the closed loop vaporisation system is used, the water intake will be significantly reduced.

Since the seawater off Jaigarh is vertically well-mixed, withdrawal of seawater can be from any depth below the lowest low tide level. However, it is advisable to draw seawater (17000 m^3/h) about 3-5 m above the bed to prevent excessive silt getting sucked particularly during monsoon. In the present case the depth of intake will depend on the design of the FSRU.

5.2.6.3 MITIGATION MEASURES

Appropriate screens should be provided in the intake to avoid large marine organisms entering the intake system. The efficiency of the intake system might decrease over a period of time due to the settlement of bio-foulers such as barnacles, at and inside the pipe opening, entry of sediment into the sump etc. Periodic removal of these materials will be required. The cleared materials should not be dumped to sea.

5.2.6.4 FSRU REJECT EFFLUENT

As discussed in Section 4 two locations have been selected for discharge of FSRU rejects (cold water and hot water). The return effluent will be discharged into the seawater through nozzles in the sides of the FSRU.

Warm water discharge

For warm water effluent release, the numerical modelling detailed in Section 4.8.3.1 clearly reveals that the time-series variation in predicted temperatures at different locations around the outfall at all tidal conditions will be insignificant except for relative high temperature limited to a small area (less than 50 m radius). The variation of temperature inside the patch around the outfall point would be in the range 28.5^0 C-29.0^0 C. Also, due to high dispersion, there will be no impact on water qualities at the shore due to the release of warm water at the proposed outfall discharge location.

The warm water effluent (2000 m^3/h) can be discharged at a depth of 8-12 m from the surface to achieve better dispersion as the lighter effluent would tend to rise through the ambient seawater of higher density.

Cold water discharge

For cold water effluent release, the numerical modelling detailed in Section 4.8.3.2 clearly reveals that the time-series variation in predicted temperatures at different locations around the outfall at all tidal conditions will be insignificant except for relatively low temperature limited to a small area around the release site (less than 50 m radius). The variation of temperature inside the patch around the outfall point would be in the range 28.5^0 C-29.0^0 C. Also, due to high dispersion, there will be no impact on water qualities at the shore due to the release of cold water at the proposed outfall discharge location.

The cold water effluent (15000 m^3/h) can be discharged at a site about 2-4 m from the sea surface depending on the design of the FSRU.

5.2.6.5 MITIGATION MEASURES

With the result output of model, it is clear that impact of cold water and warm water discharges from DFDE / turbine engines cooling water outlet and LNG vaporizer outlet will attain ambient temperature within 50 m of their discharges. Nevertheless, it is advisable to mix the two discharges before release to minimize the thermal influence further in case open loop vaporisation system is selected. This will depend on the constraints of the FSRU design and construction, given that the engine cooling water and the vaporiser water systems are often located at the opposite ends of FSRU.

During the operation phase, the marine environments need to be visually monitored for occurrence of unusual mortality of aquatic organisms around the FSRU. In addition, detailed ecological monitoring must be done periodically to ascertain the environmental integrity of the region.

The FSRU and the Port are expected to have their oil spillage contingency plans. These should be periodically reviewed so that the oil spill combating equipment is in readiness should an emergency arise.

5.2.6.6 RELEASE OF BIOCIDES / ANTIFOULANTS

Antifoulants are chemicals used to prevent marine growth and clogging of the sea water system. The frequently used antifoulant is hypochlorite. If chlorination is done, then the free chlorine (total residual oxidant in estuarine / marine water) concentration in cooling / cold water discharges should ideally be maintained at 0.2 parts per million (ppm). This is in line with the “Environment, Health and Safety Guidelines for LNG Facilities” from International Finance

Corporation’s (under World Bank) for free chlorine in cooling/cooled water. Residual chlorine present in the return water can have synergistic effects on the flora and fauna of the receiving water.

5.2.6.7 IMPACT OF FSRU EFFLUENT ON FLORA AND FAUNA

From the foregoing discussion the significant impact on flora and fauna due the operations of FSRU are essentially limited to changes in ambient water temperature and concentration of biocide in the effluent.

Each marine species has its preferred range of temperature and in most cases the species does not thrive or survive outside this range. Thus the temperature determines which organisms will thrive and which will diminish in numbers and size. Fishes occur in nature over a wide range of temperature, however, the range of tolerance of most species is narrow. Sometimes, the distribution and abundance of populations is determined by less than lethal temperatures interacting with other toxic substances when present in water.

Elevated temperatures increase the metabolism, respiration and oxygen demand of fish and other aquatic life, approximately doubling the respiration for a 10° C rise in temperature. Hence the demand for oxygen is increased under conditions where oxygen solubility is lowered. Further, sudden changes in temperature are deleterious to fish life with abrupt changes of the order of 5° C can be harmful.

5.2.6.8 MITIGATION MEARURES

The DFDE / turbine engines cooling water out let and LNG vaporizer outlet should be mixed prior to discharge into sea to minimize the thermal impact on marine water. During the operation phase, the marine environment will be closely monitored so as to check presence of unusual aquatic mortality cases. An oil spillage contingency plan will be executed in case of accidental oil spillage.

Discharges of sudden and abrupt increase / decrease in temperature may cause thermal shock to the biota. Mangroves are sturdy intertidal plants which can tolerate minor changes in environmental attributes. Mangroves occur in the Shastri estuary and the nearest habitat is about 9 km from the proposed site of the FSRU. With the predicted insignificant changes in seawater temperature subsequent to the release of the FSRU effluents, these mangroves will not be negatively influenced.

It is evident however, from Sections 4.8.3.1 and 4.8.3.2 the cloud of relative modified temperature is predicted to be limited to a small area of about 50 m radius. Further, even within the cloud the temperature is predicted to be in the range 28.5^0 C-29.0^0 C which is very close to the ambient seawater temperature. Hence, the discharge of warm water (6°C above ambient temperature) and cold water (7° C below ambient temperature) is unlikely to negatively influence the marine and estuarine flora and fauna of the Jaigarh area.

As per the Environment, Health and Safety guidelines of International Financial Corporation under World Bank for the offshore Oil & Gas Developments, Maximum difference of 3° C with respect to sea water temperature shall be maintained at 100 m distance from outfall location. Thermal impact model results indicate, the sea water temperature variation (drop) follows cyclic pattern. The maximum temperature drop is predicted as 0.32°C in spring tide at 50 m distance from above mentioned cool water outfall and for warm water discharge, the sea water temperature rise is predicated to attain ambient temperature at 50 m distance. From the modelling study it is found that the tidal hydrodynamics at proposed FSRU site are conducive for rapid dissipation of temperature (heat energy). As per prediction results, the cumulative temperature drop 0.32°C (Max.) at 50 m distance around proposed outfall locations will be well within the above mentioned guidelines limit of 3°C temperature difference and would not cause any adverse impact on surrounding marine environment.

6 ENVIRONMENT MANAGEMENT PLAN (EMP)

The guiding principal of environment management is to ensure that the perturbations due to the proposed coastal activities are within the assimilative capacity of the marine zone. This is best done by integrating into the project itself, a plan of actions for mitigating predicted adverse effects through an appropriately synthesized EMP. The EMP should deal with, control and disposal of waste from various point and nonpoint sources as well as inspection of structures and machinery to ensure reliable operations.

There should be interfaces between JSWJPL and HEGPL during design, construction and operation of the Terminal. As the proposed LNG terminal project operations become part of existing JSWJPL operations, hence the project proponent shall coordinate with port operator for all EMP aspects and it shall be ensured that the total port operations / activities including proposed project shall comply with the prescribed environmental / regulatory standards. Since FSRU is a conventional LNG carrier with additional LNG vaporisation and send out facilities installed, no construction work is involved on the project site. Hence the following EMP is suggested during operation phase.

6.1 COMPONENTS OF EMP

Following specific environmental management plan/measures are discussed in this chapter:

- Summary of project activities, associated impacts and mitigation measures including responsible agency for implementation
- Administrative and Technical Setup for Environmental Management
- Environmental Management Cell
- Institutional arrangements/framework for environment management. The summary of various project activities associated environmental impacts and proposed mitigation measures are given in Table 6.1.

6.1.1 ADMINISTRATIVE AND TECHNICAL SETUP FOR ENVIRONMENTAL MANAGEMENT

Highly qualified and experienced persons in the field of Environmental Management of Ports/offshore Operations will be considered for the positions of Environmental management. Well qualified personnel with minimum qualification of graduation in the respective discipline will be considered for the third level positions as mentioned in the organization setup.
HEGPL will develop an Environmental Management Team dedicated to:

- Identify environmental aspects, normal, abnormal and emergency conditions

- Ensure implementation of standard operating procedures as updated from time to time
- Evaluate any non-conformity to the environmental standards, as stipulated by different regulatory agencies
- Ensure and implement necessary corrective actions
- Establish procedures for reporting, document and record control
- Establish and implement procedures for incident and near miss reporting, investigation and root cause analysis and prescribe corrective action

Table 6.1: Project Activities, Associated Impacts and Mitigation Measures

Sr. No.	Activity	Relevant Environmental components likely to be impacted	Likely Impacts and their significance in the absence of Mitigation Measures	Proposed Mitigation Measures	Responsible Agency for Implementation
			Operation Phase		
1	Power generation from BOG at FSRU	Air Quality	- Stack Emissions - Emissions from LNGC during unloading	- Due to the high efficiency and the clean fuel used in a dual fuel engine in gas mode, the exhaust gas emissions when running on gas are extremely low. - Stack Monitoring - Ambient air quality monitoring will be carried out regularly at selected locations - LNGC will comply the MARPOL convention (Annex VI)	HEGPL/Vessel Operator
		Noise	- Impact due to operation of equipments such as pumps etc.., during unloading/ Send out operations - Impact due to operation of equipment during Regasification Operations - Impact due to other	- Acoustic Barriers and Enclosures - Personal Protecting Equipment (PPE) - IMO Code on Noise Levels on Board Ships, be followed	

			operations envisaged at LNG FSRU such as BoG compressors etc.,		
2	Aqueous discharges in harbour basin	Marine water quality and ecology	- Change in marine water quality/ecology due to discharge ship wastes (silage), sewage, bilge water, solid waste etc.	- Ships are prohibited from Discharging waste water, bilge, oil wastes, etc. into offshore waters near FSRU facility. - Ships would also comply with the MARPOL convention. - FSU and FSRU will comply to International Convention for the Prevention of Pollution from Ships (MARPOL) 1974/1978, Consolidated Edition, IMO, 1991, including 1992 amendments to Annex I and 2002 amendments - Provision of waste reception Facility	HEGPL/Vessel Operator
3	Cargo and Oil spills	Marine water quality and ecology	- Change in marine water quality	- Oil spill control equipment such as booms / barriers will be provided for containment and skimmers will be provided for recovery. - Response time for containment and recovery will be quicker. - An impoundment pit(s) will be	HEGPL

				provided and shall be sized according to the NFPA 59A requirements or EN1473 respectively to minimize the impact to the external and internal Facilities due to release of LNG. - A sump of provisionally 5 to 6 m cube for an LNG spill will be provided in the underside of the main LNG trestle (Elev. +15m) between the LNGC and FSU, and also on the underside of FSRU wharf - A dedicated FSRU Deluge System will be installed for the protection of the hull against possible exposure of LNG that may result in brittle fracture. The system will be a mix of drip trays and drip pans arrangements in area deemed possible to have leakage (non-welded connections), as well as a seawater deluge over the side of the hull during the LNG transfer from the FSU to FSRU. Any possible spillage areas will be provided with a coating resistant to cryogenic	

				liquids and shall be of sufficient depth as to contain a quantity of cargo at least equal to the largest credible liquid spill. - For LNG Spill, If safe to do so, stop liquid flow. Remove all ignition sources. Provide explosion-proof clearing ventilation if possible. Prevent from entering confined spaces. Use personal protective equipment	
4	Water Supply	Water resources	- Impact on existing water resources	- The cooling water and fresh water requirement during operation stages will be met from Sea water	HEGPL/Operator
5	Wastewater Discharge	Water Quality	- Impact due to discharge /disposal of untreated sewage	- On board treatment facilities at FSRU and LNGC will be made available. - Sewage from onshore receiving facility will be collected and treated	HEGPL
6	Seawater withdrawal	Marine ecology	- Impingement/Entrainment/ Entrapment of aquatic life	- Intake With proper screens will be provided - Maintaining Low Intake Velocity to minimise the Entrainment & impingement - Intake is proposed nearer to LNG FSRU and hence entrapment will be	HEGPL/Operator

				insignificant	
7	Discharge of return cold water from FSRU	Marine water and marine ecology	- Impact on Aquatic life due to decrease in temperature	- The discharge water temperature will be within 7°C below ambient seawater temperature - Discharge through properly designed marine outfall system fitted with diffusers – As per EHS Guidelines for LNG Facilities suggested by IFC, discharged cooling or cold water temperature will be ensured within 3 degrees Celsius of ambient temperature at the edge of the mixing zone or within 100 meters of the discharge point – Outfall at 2-4 m from surface to ensure minimal impact. – Ensure to follow the monitoring mechanism suggested in environmental monitoring programme	HEGPL/Operator
8	Solid Waste Management	Groundwater and Soil quality	– Impact due to disposal of solid waste on ground without treatment at ORF.	– Composted bio degradable waste will be used as manure in greenbelt. – Other recyclable wastes will be sold	HEGPL/Operator
9	Handling of hazardous wastes	Fire accidents due to products handling	– Human life and loss of property	– Hazardous wastes (used oil & used battery) will be sent to MPCB/CPCB approved	HEGPL/Operator

				recyclers. – Medical facilities including first aid will be available for attending to injured workers Emergency alarms, provision of fire hydrant system and fire station. – Effective Disaster Management Plan (DMP) which covers onsite and offsite emergency plans.	
10	Fishing activity	Fishermen livelihood	- Impact on fishing due to interference to fishing vessel	– Marker buoys at Offshore area. – Regular Interactions will be initiated with the fishing community – Conflicts if any with fishing community will be amicably resolved in all cases	HEGPL
11	Operation of port	Socio-economic conditions of the region	Local people will be given preference based on their qualification and skill set. Together with this employment potential, project will help to enhance the socio economic conditions of the area with better schooling, communication and transport facilities that will be developed/ triggered as a part of overall economic development of the region.		
		Natural Hazards	Disaster Management Plan (DMP) will be prepared; Head (EHS) will act as the overall in-charge of the control of educative, protective and rehabilitation activities to ensure least damage to life and property.		

6.1.2 INSTITUTIONAL MECHANISM FOR IMPLEMENTATION OF MITIGATION MEASURES

The effective implementation and close supervision of the environmental management to mitigate the environmental impacts, which are likely to arise due to the operational phase of the project could be achieved through a suitable institutional mechanism.

Proper institutional mechanism to understand and implement appropriate environmental management measures during various stages of the project is a pre requisite and has a strong bearing for the overall success of the project management. Implementation of the Environmental Management measures will become easy once a good project management team is in place.

6.1.3 APPROACH TOWARDS VOLUNTARY COMPLIANCE

HEGPL can adopt Environment Health & Safety Management System (EHS MS) based on recognized international standards for environmental and safety management systems (ISO 14001 – 2008; OHSAS 18001- 2007, 2008, Social Accountability (SA) 8000 and International Maritime Organisation (IMO)). The objective is to establish a system to assess, monitor and manage environmental performances, which can be used to promote continual environmental improvement and prevention of pollution. The typical procedure that can be adopted in formulating the EMS is as follows

Identify and list out environmental aspects due to the operation of the proposed project

- Determine the key operations that have significant environmental impacts
- Identify and track environmental legislations, policies, codes and other relevant requirements
- Establish objectives and targets (Environmental Management Plan)
- Formulate an Environmental Management System.

6.2 ENVIRONMENTAL MANAGEMENT CELL (EMC)

Apart from having an Environmental Management Plan, it is so also necessary to have a permanent organizational set up charged with the task of ensuring its effective implementation of mitigation measures and to conduct environmental monitoring. Identify and list out environmental aspects due to the operation of the proposed project

- Determine the key operations that have significant environmental impacts
- Identify and track environmental legislations, policies, codes and other relevant requirements
- Establish objectives and targets (Environmental Management Plan)

- Formulate an Environmental Management System.

The EMC is responsible for overall environmental activities of the proposed facility and implementation of the Environmental Management Plan (EMP) and coordination with JSWJPL in case of any requirements. The EMC's responsibility for implementing the EMP also requires regular interaction with the environment regulatory authorities such as MPCB, MCZMA, MoEF&CC and the Indian Coast Guard.

The major duties and responsibilities of Environment Management Cell are:

- To implement the environmental management plan
- Risk identification and control of environmental problems
- Evaluating the efficacy of the EIA, mitigation measures, as stipulated in the EMP.
- Coordination with JSWJPL, MoEF&CC and MPCB for prevention and control of pollution.
- To assure regulatory compliance with all relevant rules and regulations
- To ensure regular operation and maintenance of pollution control devices
- To minimize environmental impacts of operations as by strict adherence to the EMP
- To initiate environmental monitoring as per approved schedule
- Review and interpretation of monitoring as per approved schedule
- Review and interpretation of monitoring results and corrective measures in case of monitored results are above the specified limit
- Maintain documentation of good environmental practices and applicable environmental laws as ready reference
- Maintain environmental related records
- Coordination with regulatory agencies, external consultant, monitoring laboratories
- Maintain log of public complaints regarding environmental issues and the action taken

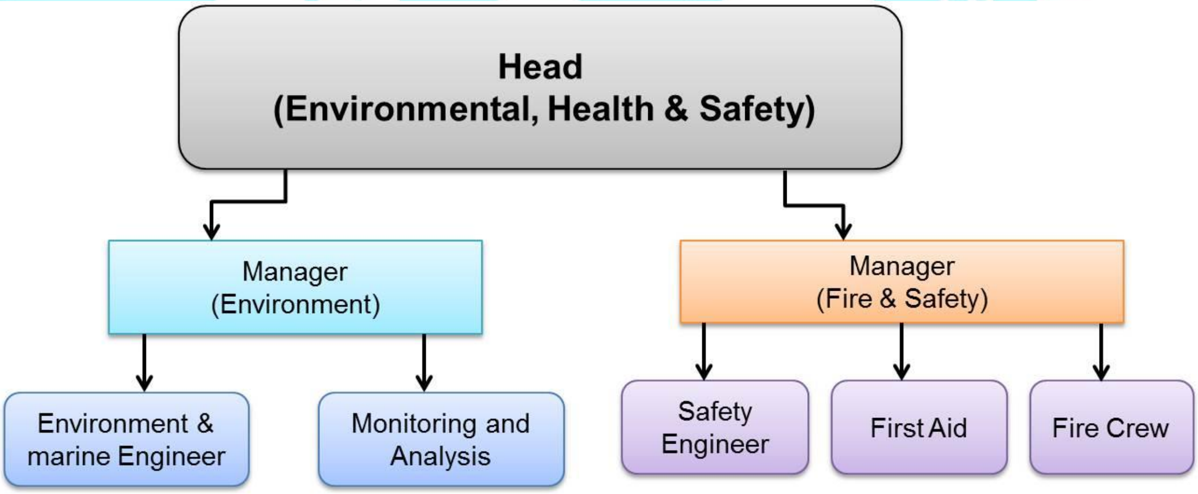
The proposed Environmental Management Cell should have all basic record keeping facilities such as hard ware/software facilities, adequate space, vehicle (transport) and basic furniture and all simple instruments such as GPS, Digital camera, Hand held noise metre etc. The cell should have all basic environmental management data of the project that includes but not limited to the following;

- Environmental Impact Assessment Report (both soft and hard copy)
- All valid and up to date environmental clearances papers
- All latest Environmental legislations, policies, codes and manuals for ready references

- A list of consultants on environmental management need to be kept with yearly revision of the list. This will help to receive proper advice in case of an emergency or a requirement and also to implement day to day environmental management activities. Over a period of time a system to understand and absorb the new revisions and changes in the environmental requirements and practices are to be established.

6.3 AUDITS AND INSPECTIONS

EMC will be responsible for implementing Compliance Assurance activities, namely environmental audits. Internal audits and reviews of environmental procedures shall be conducted annually. Third party audits of environmental procedures shall be conducted periodically. EMC also serves as a resource for HEGPL's employees regarding environmental compliance issues. The Environmental Compliance Program's main objective is to help the offshore LNG FSRU, its employees and contractors to comply with environmental regulations. The EHS Steering Committee, made up of Management Team members, shall conduct quarterly EHS performance reviews. Inputs to their review process are provided from monitoring programs, audits and inspections conducted by staff and contractors with specialised expertise in operations and EHS.



In addition to internal audits, there shall be external audits conducted by the regional office, Ministry of Environment, Forests &CC (MoEF&CC), Government of India to oversee compliance to conditions laid down by regulatory authorities. Any impact to the environment is identified, same shall be evaluated and corrective actions shall be taken.

7 POST-PROJECT ENVIRONMENTAL MONITORING

In Sections 4 baseline settings of relevant environmental components with respect to the Shastri estuary and the coastal area including the FSRU site are given in detail. These results conclude that the mouth segment of the JSWJPL, where FSRU facilities are proposed and the open shore area are unpolluted with respect to the baseline. These data can be considered as base line data for future monitoring. These data will be used to arrive at the baseline for various components of the estuarine and marine environments as well as to fix the range of each parameter within which natural variations are possible.

7.1 PERIOD OF MONITORING

Like all natural ecosystems, the estuarine and coastal marine environment also undergoes seasonal variations. Build-up of pollutants takes place in dry season particularly during summer, when the flushing due to freshwater becomes negligible. Hence, the monitoring will be carried out during April – May preferably around neap tide, once a year.

7.1.1 SAMPLING LOCATIONS

About 8 to 10 Stations will be considered for monitoring of subtidal ecology. There is no intertidal exposure observed in the study area as it is mostly hill terrain without any beaches.

7.1.2 WATER QUALITY

Water samples obtained from 2 levels in the vertical when the depths exceed 3 m, will be analyzed for temperature, pH, salinity, DO, BOD, (or total organic carbon), dissolved phosphate, nitrate, nitrite, ammonia, PHc and phenols. For water depths of less than 3 m surface samples will be collected. Areas under profound tidal influence reveal diurnal changes particularly when anthropogenic contaminants are introduced in excess of their assimilative capacity. To record such changes if any, the water quality at stations (Near FSRU) will be assessed for selected parameters (pH, salinity, DO, ammonia) over a tidal cycle with 1 h sampling frequency.

7.1.3 SEDIMENT QUALITY

Sediment from subtidal stations will be analysed for texture, organic carbon, phosphorus, chromium, nickel, copper, zinc, cadmium, lead, mercury and PHc.

7.1.4 FLORA AND FAUNA

Biological characteristics will be assessed based on phytopigments, phytoplankton populations and their genetic diversity; biomass, population and species diversity of zooplankton; biomass, population and species diversity of benthos and fish quality

7.1.5 MANGROVES: Patches of mangroves which exists about 9 km from the project site will also be monitored.

7.2 FREQUENCY OF MONITORING

First monitoring	:	Prior to the operational phase.
Second monitoring	:	After 6 months from commencement of operations.
Third monitoring	:	After 12 months from commencement of operation
General monitoring	:	Once every year from completion of third phase of monitoring.

7.3 ASSESSMENT

The results of each monitoring will be carefully evaluated to identify changes if any, beyond the natural variability identified through baseline studies. If gross deviation from the baseline is found, the port operations will be evaluated to identify the causative factors leading to these deviations and accordingly, corrective measures to reverse the trend will be taken if necessary.

8 PROJECT BENEFITS

Given the need for sustainable development, it is today the endeavor of the industry & the policy makers to promote projects which have least environmental impact; positive social benefits; and potential to assist in overall development of nation. HEGPL LNG terminal is such a project & the construction of the LNG terminal would bring in general prosperity in area and would serve not only the local but also the nation as a whole. The economic activity will take a boost & there will be direct & indirect employment generation. Supporting facilities created as a part of the LNG terminal would also benefit the local community.

The LNG Terminal shall bring social benefits across the region by having consistent & reliable energy source; hence it is recommended that the project should be pursued while trying to optimize the costs and schedule. General benefits of major developments like LNG terminal are not only restricted to the financial benefits to proponent and government but also have several societal benefits. Benefits go beyond investment and returns due to the social gains from the project, i.e. improvement in quality of life by an improvement in physical & social infrastructure, employment generation etc. Project is expected to fuel industrial growth in the region it shall also open up avenues for indirect employment for local population. Since the LNG project is FSRU based, it will provide safe, sustainable and economic means of import, re-gasification and further distribution of natural gas in the state/country.

9 SUMMARY AND CONCLUSION

9.1 THE PROJECT

H-Energy Gateway Private Limited (HEGPL); erstwhile Hiranandani Gas Company Private Limited, is planning on establishing and operating an 8 million metric ton per annum (MMTPA) Liquefied Natural Gas (LNG) Storage & Re-gasification Project at JSW Jaigarh Port on the west coast of India in Maharashtra by entering in a sub-concession agreement with JSW Jaigarh Port Ltd (JSWJPL). The Project is in close proximity to GAIL's Dahej-Uran- Panvel-Dabhol pipeline (DUDPPL), as well as Dabhol-Bangalore Pipeline (DBPL). The project intends business users to use the LNG terminal facilities for import, storage & regasification on a tolling basis. The environmental clearance was for the water front Jetty, the approaches and the on shore facility including the storage tanks (2 nos and with another one in future), regasification, loading and despatch facilities. However, with the demand of gas especially on the Konkan Coast of Maharashtra, is taking time to pick up and does not warrant establishment of a full scale land based facility. In addition, the establishment of the land based facility would take considerable time, on account of scale of construction involved. Accordingly, HEGPL intends to develop the project in a phased manner, Phase I which will be the Early Production Phase (EPF) consisting of a Floating Storage, Regasification Unit (FSRU) moored at the LNG jetty in Jaigarh port. While the waterfront structures will remain identical, the land based structures will be reduced considerably, since the regasification and the storage unit will be located on the Floating storage and regasification unit (FSRU).

9.2 PROPOSED DEVELOPMENT AND CRZ NOTIFICATION – 2011

Ministry of Environment Forest & Climate Change (MoEF&CC) vide letter dated 19th December 2013 has issued environmental and CRZ clearance to M/s JSWV Jaigarh Port Ltd. For expansion of JSW port at Jaigarh, Ratnagiri, Maharashtra. Further, MoEF&CC vide letter dated 3.3.2015 has transferer the environmental clearance & CRZ clearance from JSW Jaigarh Port to M/s H Energy Gateway Pvt. Ltd. The clearance includes 8 MTPA shore tankage based LNG terminal. The clearance includes 8 MTPA shore tankage based LNG receiving terminal, re-gasification and send-out facility.

The present report is prepared to meet the requirements of the recommendation of the EAC held on 24th October 2016. The report establishes the prevailing ecological status of the marine and estuarine environment based on field studies with respect to water quality, sediment quality, biological characteristics and their comparison with historical data wherever available. The report also analyses probable environmental perturbation due to the proposed FSRU and related activities at JSW Jaigarh Port. Jaigarh Based on the assessment of impacts, mitigation measures to minimize these impacts in terms of a structured Environment Management Plan (EMP) are suggested.

9.3 FIELD INVESTIGATION

Field studies were carried out at 10 locations covering 12 km off the JSWJPL. Subtidal sampling for water quality, sediment and flora and fauna was done over the estuarine stretch of about 9 km between JSW port and station 6. Stations 4, 5 and 6 were in the Shastri Estuary and stations 9 and 10 were sampled in the proposed FSRU location. Stations 1 to 3 and 8 represent near coastal region, whereas the station 7 represents offshore region.

9.3.1 ASSESSMENT OF WATER QUALITY

- The water temperature was in the range of 26.5-29.5°C. Variations in temperature between the surface and the bottom were minor suggesting vertically well-mixed water mass. Temporal variation of water temperature was minor.
- pH was in the range of seawater and varied between 8.0 to 8.2.
- The study area sustains relatively lower concentration of SS. However, seasonal disturbances was discernable in terms of variation in SS concentration.
- Average salinity of coastal water was 35.2 ppt. Tidal vatiation was recorded in the estuarine segment of Shastri estuary and. However, at station J10, which represents the FSRU site, the salinity variation was only 0.2 ppt, revealing the absence of freshwater influence at the site.
- Average DO was recorded to be above 5.5 mg/l in the area indicating the area is free from any organic waste. However, some deviations were recorded in the estuarine segment indicating some local influence.
- Concentrations of phosphate, nitrate, nitrite and ammonia was low, indicating no anthropogenic inputs in the area.
- Similarly the PHc and phenolic compound values during present study varied randomly with no clear trends. However, the values were lower than recommended for water quality criteria for designated best use for salt pans, shell fishing, mariculture and ecologically sensitive zones by the Central Pollution Control Board (CPCB).

9.3.2 ASSESSMENT OF SEDIMENT QUALITY

The results of sediment analyses indicated considerable variation of trace metals of concern such as chromium, nickel, copper, zinc and mercury along the estuary and coastal region and. The coastal sediment of the Ratnagiri district being largely derived from the lateritic and basaltic terrain, is high in Fe and Mn and other trace metals and observed values can be considered as baseline in the absence of significant anthropogenic source to the coastal area of Jaigarh. Results of organic carbon and phosphorus analysis recorded during the present study indicate high natural variability probably due to the textural differences of the sediment. There was no build up of PHC in sediment of the region.

9.3.3 ASSESSMENT OF FLORA AND FAUNA

Important biological parameters which are considered for assessment in the present study are phytoplankton, zooplankton, benthos and fishes. The following conclusions are drawn based on the present and the past monitoring results:

- Total coliforms and fecal coliforms which are indicators of fecal pollution were below the detectable limits almost at all the sampling sites. Pathogenic organisms such as *Salmonella* like organisms, Shigella like organisms and Vibrio like organisms were present at majority of the sampling sites. The total viable bacterial populations in sediments ranged widely from 100 x 10^2CFU/ml to as high as 27000 x 10^2CFU/g. Total coliforms and fecal coliforms which are indicators of fecal pollution were below the detectable limits almost at all sampling sites. Fecal indicator bacteria like *Escherichia coli* and *Streptococcus fecalis* were also below the detectable limits.
- The distribution of chlorophyll *a* was patchy with values fluctuating from 0.3 to 5.1 mg/m^3 (av. 0.4 to 4.1 mg/m^3). Upper estuarine region sustained higher chlorophyll concentration (4.7 and 5.1 mg/m^3) due to proximity to shore where high nutrient was found. Similar to chlorophyll *a*, the distribution of phytoplankton population revealed the temporal and spatial variation with higher levels in near shore water than the offshore. Overall the results of phytoplankton revealed a good productivity both in terms of phytoplankton biomass and population with fairly good generic diversity.
- There were no mangroves at and near the proposed project site. However, mangroves are present in the Shastri Estuary around 9.0 km away from the proposed FSRU.
- Zooplankton in terms of biomass and population wasindicative of an overall good secondary production potential of the region during the study period. The results indicate wide variations in the standing stock of zooplankton throughout the study area. The percentage composition of zooplankton consisted of high population of copepods (av. 86.4%), decapod larvae (av. 2.6%), Siphonophores (av. 3.1%) and lamellibranchs (av. 2.2%). In general, the study area sustained low numerical abundance of fish larvae probably because the study area was not the breeding grounds of fishes.
- The data of the macrobenthic productivity in terms of biomass and population varied widely in each segment, as commonly observed for coastal areas under high tidal influence. Estuarine and coastal sediment recorded relatively high meirobenthic standing stock in terms of biomass and population due to dominance of nematodes, foraminiferans and copepods. Major faunal

component in the study area were nematodes followed by foraminiferans. Overall, 11 faunal groups were recorded in the area.

- Corals are absent off Jaigarh. In fact the area sustains high percentage of silt and clay – the conditions unfavourable for the reef-building corals to thrive. Dolphins (*Delphinus delphis*) were recorded in the region during the study period. Eight birds were recorded during study period in Jaigarh region.

9.3.4 PHYSICAL PROCESSES

The physical processes influencing dynamics of estuaries and coastal zones are tides, currents, waves and land runoff while bathymetry provides information on the water depth. The information of these parameters is necessary while assessing the impacts of coastal developments on the aquatic environment.

- Near JSW port area, 10 m contour is located at 0.5 Km from the low tide line. However, north of the Jaigarhh head consists of Narwan Bay and the distance of the low tide line from the 10 m contour is around 3 Km. In the middle of these two bays, river Shastri is joined and at the mouth of the Shastri estuary low depth of around 2.5 m below CD are found. However, at Jaigarhh fort depth of more than 15 m are available. Large mudflats are situated in the estuarine zone in the southern side.
- The data recorded in the region indicates that the spring tidal range was 3.0 m and neap range was 1.0 m. This shows that maximum tidal range at this location is 3 m. The average time lag between Apollo Bunder and Malvan was 1h 10 min in spring and 2 h in neap.
- Maximum current observed in the region was 0.55 m/s. The direction veered between 50^{o} and 300^{o}. This indicate that the currents changed from NE to NW direction in a tidal cycle which shows that the current were parallel to the coastline.
- Circulation patter in the region indicates that excursion length of 5.4 km in 4h 15 min in the flood condition while it was 3.5 km in 5h 30 min during ebb. Hence a particles released at station FSRU site would move in the Shastri estuary during flood and southward along the coast when released during ebb.
- Dedicated software Hydrodyn - FLOSOFT and Hydrodyn - POLSOFT for prediction of tides and currents and dispersion (pollutant transport) processes in the seas and estuaries developed at Environ Software (P) Ltd, Bangalore, were utilized for the studies. The modelling results hot and cold water dispersion indicates that there will be noticeable increase or decrease in water temperature beyond 50 m due to hot and cold water discharge from the FSRU.

9.4 ANTICIPATED ENVIRONMENTAL IMPACTS & MITIGATION MEASURES

Since, there is no specific construction work involved on project site for FSRU,there will not be significant negative impact of FSRU. The most significant impact on the sea water quality would be due to discharge of cold water in the event of selection of open loop regasification. In commissioning phase the discharge volumes will be relatively less and for limited time period. Due to the small quantities of discharge associated with the commissioning phase, potential impacts on the marine environment are expected to be of low significance.

9.4.1 IMPACT DUE TO SEAWATER INTAKE

The proposed project is expected to pump around 17000 m^3/h sea water for regasification of LNG and cooling of machinery in the event of the open loop vaporisation system. The impact associated with the intake is due to Impingement, entrapment and entrainment of marine organisms. The volume of seawater intake and the cooled seawater discharge including the associated antifoulants in the effluent has the potential to impact juvenile fish. In the event that the closed loop vaporisation system is used, the water intake will be significantly reduced. Since the seawater off Jaigarh is vertically well-mixed, withdrawal of seawater can be from any depth below the lowest low tide level. However, it is advisable to draw seawater (17000 m^3/h) about 3-5 m above the bed to prevent excessive silt getting sucked particularly during monsoon. In the present case the depth of intake will depend on the design of the FSRU.

9.4.2 MITIGATION MEASURES

Appropriate screens should be provided in the intake to avoid large marine organisms entering the intake system. The efficiency of the intake system might decrease over a period of time due to the settlement of bio-foulers such as barnacles, at and inside the pipe opening, entry of sediment into the sump etc. Periodic removal of these materials will be required. The cleared materials should not be dumped to sea.

9.4.3 FSRU Reject Effluent

Warm water discharge

The modelling result indicates that the variation of temperature inside the patch around the outfall point would be in the range 28.5^0 C-29.0^0 C. Also, due to high dispersion, there will be no impact on water qualities at the shore due to the release of warm water at the proposed outfall discharge location. The warm water effluent (2000 m^3/h) can be discharged at a depth of 8-12 m from the surface to achieve better dispersion as the lighter effluent would tend to rise through the ambient seawater of higher density.

Cold water discharge

Cold water discharge modelling clearly reveals that the time-series variation in predicted temperatures at different locations around the outfall at all tidal conditions will be insignificant except for relatively low temperature limited to a small area around the release site (less than 50 m radius). The variation of temperature inside the patch around the outfall point would be in the range 28.5^0 C-29.0^0 C. Also, due to high dispersion, there will be no impact on water qualities at the shore due to the release of cold water at the proposed outfall discharge location. The maximum temperature drop is predicted as 0.32°C in spring tide at 50 m distance from the point of disposal.

9.4.4 RELEASE OF BIOCIDES / ANTIFOULANTS

Antifoul-ants chemicals are used to prevent marine growth and clogging of the sea water system. The frequently used antifoul-ant is hypochlorite. If chlorination is done, then the free chlorine (total residual oxidant in estuarine / marine water) concentration in cooling / cold water discharges should ideally be maintained at 0.2 parts per million (ppm). This is in line with the "Environment, Health and Safety Guidelines for LNG Facilities" from International Finance Corporation's (under World Bank) for free chlorine in cooling/cooled water. Residual chlorine present in the return water can have synergistic effects on the flora and fauna of the receiving water.

9.4.5 IMPACT OF FSRU EFFLUENT ON FLORA AND FAUNA

In the present project the significant impact on flora and fauna due the operations of FSRU are essentially limited to changes in ambient water temperature and concentration of biocide in the effluent.

Majority of the phytoplankton, zooplankton, benthic organisms and fish present in the area can tolerate and adopt up to 10°C raise/fall in the sea water temperature due to warm/cool water discharges subject to the absence of sudden and abrupt increase / decrease in temperature. Mangroves occur in the Shastri estuary and the nearest habitat is about 9 km from the proposed site of the FSRU. With the predicted insignificant changes in seawater temperature subsequent to the release of the FSRU effluents, these mangroves will not be negatively influenced.

The cloud of relative modified temperature is predicted to be limited to a small area of about 50 m radius. Further, even within the cloud the temperature is predicted to be in the range 28.5^0 C-29.0^0 C which is very close to the ambient seawater temperature. Hence, the discharge of warm water (6°C above ambient temperature) and cold water (7°C below ambient temperature) is unlikely to negatively influence the marine and estuarine flora and fauna of the Jaigarh area.

9.5 ENVIRONMENT MANAGEMENT PLAN

The FSRU will be fitted with a cold vent used for emergency only. There will be no flaring on the FSRU. The boil of gas (BOG) will be used as fuel for DFDE on FSRU. The FSRU will be built to meet the technical safety requirements from the Classification Society. The following is a summary of the main safety features related to the shutdown of the FSRU, demonstrating that the FSRU is able to shut down and sail away at short notice. Vent masts to be installed, one for each cargo tank, to ensure quick relief of the cargo tank pressure, in case of exceeding high pressure. Additionally, a high pressure emergency gas relief vent mast will be installed to ensure quick relief of the high pressure gas downstream the regasification plant in cases of emergency. The project proponent shall develop and implement a Health, Safety, Security, Environmental and Social Performance Management System (HSSE&SP-MS) for different phases of the project. This HSSE&SP-MS will be set up to formulate, implement and monitor: plans, policies and actions encompassing Health, Safety, Security, Environment and Social Performance. The EPC contractors will be obliged by contract, to follow the HSSE&SP Management System during construction and commissioning phases.

A Waste Management Plan will be developed for waste collection, handling and disposal facilities for proposed project for environmentally compatible waste management. This plan has been drawn, in accordance with the latest MARPOL Regulations and also as MPCB / CPCB / MoEF & CC guidelines with respect to hazardous wastes and solid wastes. The solid and hazardous wastes generated from the marine based facilities, i.e. operational FSRU, LNGC, tugs, dredgers etc. will be collected twice in a week on jetty disposed at shore through JSWJPL authorised mechanism. The type of waste, source and quantity will be noted and weighed before it is disposed of at an authorised waste disposal site. The spent batteries and spent oil shall be disposed through buy back option and the record of the same is maintained.

9.6 POST-PROJECT ENVIRONMENTAL MONITORING

In baseline settings of relevant environmental components with respect to the Shastri estuary and the coastal area including the FSRU site are given in detail. These results conclude that the mouth segment of the JSWJPL, where FSRU facilities are proposed and the open shore area are unpolluted with respect to the baseline. These data can be considered as base line data for future monitoring. These data will be used to arrive at the baseline for various components of the estuarine and marine environments as well as to fix the range of each parameter within which natural variations are possible.

9.7 PROJECT BENEFITS

The LNG Terminal shall bring social benefits across the region by having consistent & reliable energy source; hence it is recommended that the project should be pursued while trying to optimize the costs and schedule. General benefits of major developments like LNG terminal are not only restricted to the financial benefits to proponent and government but also have several societal benefits. Benefits go beyond investment and returns due to the social gains from the project, i.e., improvement in quality of life by an improvement in physical & social infrastructure, employment generation etc. Project is expected to fuel industrial growth in the region it shall also open up avenues for indirect employment for local population. Since the LNG project is FSRU based, it will provide safe, sustainable and economic means of import, re-gasification and further distribution of natural gas in the state/country.

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Table 4.4.1: Water quality of Jaigarh during March 2017

Parameter	Level	J1	J2	J3			J4			J5			J6		
		Avg*	Avg*	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
	S	27.5	28.0	28.3	28.3	28.3	26.5	29.0	28.0	27.0	28.0	27.5	27.0	27.5	27.3
Temperature(°C)	B	27.0	27.5	27.8	27.8	27.8	27.0	28.5	27.7	26.5	27.5	27.0	26.5	27.0	26.8
		(27.5)	(28.5)	(29.0)	(29.0)	(29.0)	(23.0)	(30.0)	(27.5)	(26.5)	(28.8)	(27.7)	(26.5)	(28.5)	(27.5)
pH	S	8.2	8.2	8.2	8.2	8.2	7.9	8.0	8.0	7.9	8.0	8.0	7.9	8.0	8.0
	B	8.2	8.2	8.2	8.2	8.2	7.9	8.0	8.0	7.9	8.0	8.0	7.9	8.0	8.0
SS(mg/l)	S	13	15	19	19	19	22	23	22	18	18	18	17	21	19
	B	17	19	19	19	19	21	127	74	22	33	28	20	22	21
Turbidity(NTU)	S	2.3	4.2	3.7	6.1	4.9	1.9	5.8	3.3	2.1	2.1	2.1	2.2	2.8	2.5
	B	1.6	2.4	2.4	3.5	2.9	2.1	30.8	10.6	6.8	7.1	7.0	2.9	3.6	3.2
Salinity(ppt)	S	35.3	35.3	35.4	35.4	35.4	34.6	35.3	35.1	34.6	35.3	34.9	33.9	35.2	34.6
	B	35.2	35.2	35.2	35.2	35.2	34.8	35.3	35.2	35.1	35.4	35.3	33.7	35.1	34.4
DO (mg/l)	S	6.0	6.2	6.0	6.3	6.2	4.4	6.0	5.6	6.0	6.3	6.2	6.3	6.7	6.5
	B	6.3	6.3	5.7	6.0	5.9	5.1	6.3	5.7	6.3	6.3	6.3	6.3	6.7	6.5
BOD (mg/l)	S	2.9	3.2	2.9	2.9	2.9	2.2	2.5	2.4	3.2	3.2	3.2	2.9	3.2	3.0
	B	2.9	2.9	1.9	3.2	2.5	2.9	2.9	2.9	1.9	2.9	2.4	1.9	3.8	2.9
PO_4^{3-}-P (µmol/l)	S	0.4	0.6	0.6	0.8	0.7	0.2	1.3	0.5	0.4	0.7	0.5	0.3	0.3	0.3
	B	0.5	0.5	0.4	0.6	0.5	0.2	0.9	0.5	0.4	0.7	0.5	0.5	0.6	0.6
TP(µmol/l)	S	1.6	1.7	1.2	1.6	1.4	1.1	1.5	1.3	1.1	1.3	1.2	0.9	1.1	1.0
	B	1.5	1.3	1.5	1.5	1.5	1.3	1.5	1.4	1.2	1.3	1.3	1.0	1.0	1.0
NO_3^--N (µmol/l)	S	0.3	1.2	4.9	5.2	5.0	0.1	1.0	0.5	0.4	0.8	0.6	0.4	0.7	0.6
	B	0.4	0.8	2.4	3.4	2.9	0.0	1.1	0.6	0.7	1.0	0.8	0.3	0.7	0.5
NO_2^--N(µmol/l)	S	0.1	0.2	0.2	0.2	0.2	0.1	0.6	0.3	0.2	0.2	0.2	0.1	0.1	0.1
	B	0.2	0.2	0.2	0.2	0.2	0.1	0.6	0.2	0.2	0.3	0.2	0.1	0.2	0.2
NH_4^+-N(µmol/l)	S	2.0	2.0	1.8	2.2	2.0	0.6	3.2	1.5	0.9	1.0	1.0	0.8	3.5	2.1
	B	0.8	1.3	1.2	1.4	1.3	0.8	2.2	1.4	0.6	1.4	1.0	1.1	9.2	5.2
TN(µmol/l)	S	5.9	5.9	7.7	8.4	8.0	5.9	7.6	6.7	5.0	5.8	5.4	6.6	9.8	8.2
	B	6.6	5.8	7.9	10.1	9.0	6.5	8.3	7.4	6.0	6.8	6.4	14.3	15.2	14.8
PHc(µg/l)	1m	5.7	10.7	6.0	11.7	8.8	9.2	16.7	12.9	12.6	22.2	17.4	6.9	7.3	7.1
Phenol (µg/l)	S	38.9	13.9	2.6	3.4	3.0	3.4	19.9	11.6	3.4	9.1	6.2	3.1	12.0	7.6

Continued….

*Average of two readings
Air temperature given in parenthesis

Table 4.4.1: (continued 2)

Parameter	Level	J7	J8	J9			J10
		Avg*	Avg*	Min	Max	Avg	Avg*
	S	29.0	29.5	28.0	29.0	28.5	28.5
Temperature(°C)	B	28.5	29.0	27.0	28.5	28.0	28.0
		(30.0)	(30.0)	(26.0)	(29.0)	(27.6)	(28.0)
pH	S	8.2	8.1	8.0	8.2	8.1	8.1
	B	8.2	8.1	8.1	8.2	8.2	8.1
SS(mg/l)	S	16	16	18	20	19	16
	B	21	19	15	16	16	23
Turbidity(NTU)	S	1.9	1.1	2.1	5.2	3.6	4.9
	B	3.5	2.6	2.8	3.0	2.9	6.6
Salinity(ppt)	S	35.2	35.3	35.3	35.5	35.4	35.4
	B	35.3	35.2	35.2	35.4	35.3	35.2
DO (mg/l)	S	6.2	6.4	5.4	6.3	6.0	6.2
	B	6.0	6.1	5.4	6.3	5.8	5.9
BOD (mg/l)	S	2.9	2.6	2.9	2.9	2.9	3.8
	B	2.5	3.2	2.5	2.9	2.7	2.9
PO_4^{3-}-P (µmol/l)	S	0.4	1.0	0.1	0.7	0.3	0.4
	B	0.6	0.7	0.2	0.7	0.4	0.5
TP(µmol/l)	S	0.9	2.5	1.3	1.7	1.5	1.5
	B	0.9	2.0	1.4	1.5	1.5	2.3
NO_3^--N (µmol/l)	S	23.3	2.4	1.7	4.8	3.1	0.2
	B	11.9	1.4	2.3	4.9	3.5	0.2
NO_2^--N(µmol/l)	S	ND	ND	0.1	0.2	0.1	0.1
	B	ND	0.1	0.1	0.3	0.1	0.2
NH_4^+-N(µmol/l)	S	1.7	1.1	1.1	2.9	1.8	1.1
	B	1.8	1.6	0.9	2.6	1.2	1.2
TN(µmol/l)	S	33.9	6.5	8.0	8.8	8.4	6.1
	B	35.3	8.5	7.7	8.6	8.1	8.3
PHc(µg/l)	1m	10.4	19.2	9.1	9.6	9.4	6.7
Phenol (µg/l)	S	4.3	10.7	19.9	20.9	20.4	15.1

* Average of two readings
Air temperature given in parenthesis
ND- below Dectectable level

Table 4.5.1: Sediment quality of Jaigarh During march 2017

Station Code	Sand (%)	Silt (%)	Clay (%)	Al (%)	Cr (µg/g)	Mn (µg/g)	Fe (%)	Co (µg/g)	Ni (µg/g)	Cu (µg/g)	Zn (µg/g)	Hg (µg/g)	P (µg/g)	Corg (%)	PHc* (µg/g)
J1	1.0	45.1	53.9	9.9	213	1104	12.1	56	91	175	128	0.07	1702	2.7	0.3
J2	42.1	28.4	29.5	8.9	193	889	10.5	49	78	136	114	0.06	1094	2.5	0.4
J3	34.5	31.4	32.6	6.6	193	1215	11.8	82	65	147	121	0.07	1162	2.3	0.8
J4	26.7	62.7	10.6	8.9	211	1322	13.0	62	80	195	144	0.09	1268	2.9	0.8
J5	2.2	68.0	29.8	9.2	210	1753	13.7	66	86	219	142	0.13	1499	4.4	0.2
J6	16.3	50.3	33.4	8.0	266	1887	18.1	114	98	323	214	0.10	1309	4.1	0.2
J7	1.6	68.6	29.8	7.7	210	1114	12.8	68	72	164	137	0.08	1222	2.6	0.5
J8	2.2	69.6	28.2	8.7	182	809	10.0	42	75	118	106	0.11	1020	2.7	0.5
J9	3.6	85.0	11.4	8.4	197	1105	11.5	54	75	146	128	0.12	1349	2.9	0.7
J10	5.0	84.6	10.4	8.5	202	1340	12.0	62	76	162	126	0.09	1472	2.5	0.5

Remark: *On wet wt. basis

Table 4.6.1: Microbial counts in surface water (CFU/mL) of Jaigarh (JSW) during March 2017 (Premonsoon)

Type of Bacteria	**Station**														
	J1 Spot	**J2 Spot**	**J3 Tidal**		**J4 12 Hours**		**J5 Tidal**		**J6 Tidal**		**J7 Spot**	**J8 Spot**	**J9 12 Hours**		**J10 Spot**
			Ebb	Fld	Ebb	Fld	Ebb	Fld	Ebb	Fld			Ebb	Fld	
TVCX10^{3}	100	18	300	1440	20	15	40	20	50	15	80	2800	5	2	60
TC	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
FC	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
ECLO	NG	1	1	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
SHLO	NG	8800	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
SLO	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
PKLO	NG	19	3	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
VLO	NG	NG	600	20	150	800	NG	40	200	160	NG	NG	NG	NG	NG
VPLO	NG	NG	NG	NG	NG	NG	NG	NG	50	NG	NG	NG	NG	NG	NG
VCLO	NG	NG	600	20	150	800	NG	40	150	160	NG	NG	NG	NG	NG
PALO	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
SFLO	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG

NG - No Growth

Table 4.6.2: Microbial counts in sediment (CFU/g) of Jaigarh (JSW) during March 2017 (Premonsoon).

Type of Bacteria	Station									
	J1 SPOT	J2 Spot	J3 Tidal	J4 12 Hours	J5 Tidal	J6 Tidal	J7 spot	J8 Spot	J9 12 Hours	J10 Spot
TVCX10^3	20	20	600	30	10	20	2700	2400	44	200
TC	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
FC	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
ECLO	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
SHLO	NG	NG	NG	NG	NG	NG	NG	NG	NG	9
SLO	NG	NG	NG	4	NG	NG	NG	NG	NG	NG
PKLO	NG	NG	NG	2240	NG	640	NG	NG	NG	NG
VLO	17	40	25	1900	1100	1200	66	2640	2	25
VPLO	14	NG	NG	NG	NG	NG	NG	NG	NG	NG
VCLO	3	40	25	1900	1100	1200	66	2640	2	25
PALO	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
SFLO	NG	NG	NG	17	NG	NG	NG	NG	NG	NG

NG - No Growth

Table 4.6.3: Range and average (parenthesis) of phytopigment count at different stations of Jaigarh during March 2017.

Station	Date	CHLOROPHYLL				PHAEOPHYTIN				RATIO			
		S		B		S		B		S		B	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
		Avg		Avg		Avg		Avg		Avg		Avg	
J1	04-03-17	0.7	0.8	0.7	0.7	0.2	0.2	0.2	0.2	4.5	4.7	2.8	3.9
		0.7		0.7		0.2		0.2		4.6		3.4	
J2	04-03-17	0.8	0.8	0.7	0.7	0.2	0.3	0.2	0.3	2.8	4.2	2.9	3.5
		0.8		0.7		0.2		0.2		3.5		3.2	
J3	04-03-17	1.1	3.1	1.2	1.3	0.2	0.5	0.3	0.8	6.3	6.4	1.7	3.6
		2.1		1.3		0.3		0.5		6.3		2.7	
J4	05-03-17	2.1	3.8	2.4	3.3	0.4	2.8	0.6	3.0	1.2	7.9	1.0	5.5
		3.0		3.0		0.8		1.7		5.2		2.5	
J5	05-03-17	3.2	4.7	2.6	3.4	0.6	0.7	0.8	1.2	5.5	6.6	2.2	4.5
		3.9		3.0		0.6		1.0		6.0		3.4	
J6	05-03-17	2.8	3.7	3.1	5.1	0.7	0.9	0.7	1.6	4.1	4.2	2.0	7.3
		3.3		4.1		0.8		1.1		4.1		4.6	
J7	02-03-17	0.3	0.4	1.0	1.1	0.0	0.1	0.5	0.8	5.3	16.5	1.4	1.9
		0.4		1.0		0.0		0.6		10.9		1.6	
J8	02-03-17	0.4	0.4	1.1	1.1	0.0	0.0	0.3	0.3	21.5	43.0	3.8	3.8
		0.4		1.1		0.0		0.3		32.3		3.8	
J9	03-03-17	1.0	1.9	0.8	1.5	0.4	0.9	0.4	1.0	1.3	4.1	0.9	3.1
		1.4		1.0		0.6		0.6		2.7		2.0	
J10	06-03-17	2.8	3.4	2.4	2.6	0.6	1.3	1.0	1.6	2.2	5.7	1.5	2.8
		3.1		2.5		1.0		1.3		3.9		2.1	

Table 4.6.4: Range and average of phytoplankton population count at different Stations of Jaigarh during March 2017.

Station	Date	Time & Tide	Cell count (no x 10^3 cell/L)		Total genera	
			S	B	S	B
J1	04-03-17	800 Fl-Eb	11.2	8.2	8.0	7.0
J2	04-03-17	835 Fl-Eb	16.6	29.0	11.0	11.0
J3	04-03-17	910 F.EB	34.8	33.6	11.0	11.0
		1545 F.Fl	51.4	44.4	13.0	14.0
J4	05-03-17	1000 F.Eb	409.6	269.8	14.0	15.0
		1645 F.Fl	141.8	89.0	16.0	12.0
J5	05-03-17	1000 F.EB	97.6	198.6	19.0	18.0
		1700 F.Fl	161.0	120.8	20.0	18.0
J6	05-03-17	930 F.EB	224.6	132.4	18.0	17.0
		1715 F.Fl	470.0	220.4	23.0	21.0
J7	02-03-17	1630 Fl-Eb	8.8	10.8	7.0	9.0
J8	02-03-17	1500 Fl-Eb	18.6	25.6	9.0	12.0
J9	03-03-17	800 F.EB	176.6	128.4	16.0	17.0
		1500 F.Fl	219.8	123.2	17.0	14.0
J10	06-03-17	1030 Eb-Fl	90.4	43.0	15.0	16.0

Table 4.6.5: Percentage composition of phytoplankton population at different station of Jaigarh during March 2017

Genera name	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	Total Avg.
Alexandrium				1.3						6.0	0.7
Amphidinium								9.0			0.9
Amphiprora		0.4			0.7	0.2				1.5	0.3
Asteromphalus									<0.1		<0.1
Aulacoseira								4.5			0.5
Bacillaria						2.1					0.2
Bacteriastrum									<0.1		<0.1
Bellerochea	16.5				1.4	0.2		14.5			3.3
Ceratium			0.1		<0.1				<0.1	1.5	0.2
Chaetoceros		0.4	1.2	5.8	4.2	5.7			4.4	1.5	2.3
Cocconies			1.2	<0.1	0.3						0.2
Coscinodiscus	2.1	4.4	3.7	1.5	0.8	0.8	10.2			3.0	2.6
Cyclotella		0.4	2.7	0.4	1.5	1.0		4.5	3.1		1.4
Cylindrotheca	20.6	48.2	24.4	8.6	14.5	5.3		9.0	18.5	7.5	15.7
Dactyliosolen			18.3	36.3	27.0	50.4		13.6	0.9	1.5	14.8
Dinophysis					<0.1						<0.1
Ditylum		0.4				<0.1					<0.1
Eucampia				0.5							<0.1
Eutreptiella			2.4	0.2	0.3						0.3
Fragillaria				10.3	<0.1	2.3					1.3
Gonyaulax									0.6		<0.1
Guinardia			8.5	9.4	2.2	1.5	10.2		3.9	1.6	3.7
Gymnodinium			1.2	3.2	0.7	0.2			2.2	3.0	1.0
Gyrodinium			1.3		0.7	0.2	11.2	5.0	11.1	6.0	3.6
Gyrosigma	3.1	8.8	0.2	0.5	0.8	0.2					1.4
Hemiaulus									0.7		<0.1
Lauderia						1.4			<0.1		0.1
Lithodesmium				0.3	0.1	1.3				13.5	1.5
Mallomonas	11.3	4.4	2.4	0.2	1.0	0.4		0.9		10.5	3.1
Navicula	20.6	4.8	3.8	1.8	1.1	2.9	1.0		2.5	3.0	4.1
Nitzschia	1.0	13.2	12.3	1.3	3.5	3.9	1.0	4.5	0.7	0.3	4.2
Noctiluca			1.3			0.2		0.5			0.2
Odontella				0.9	<0.1		11.2		0.6	0.1	1.3
Peridinium	20.6		0.1		1.0	0.2			5.2	1.5	2.9
Plagioselmis									3.1		0.3
Pleurosigma	2.1	2.6	0.2		0.3	0.2	1.0	1.4	0.2		0.8
Preperidinium						0.2					<0.1
Prorocentrum	1.0	4.8	1.2	0.7	0.5	<0.1		4.5	1.6	12.0	2.6
Pseudonitzschia		0.4	6.2	5.6	8.3	5.9	20.4	4.5	16.0	9.1	7.7
Rhizosolenia		4.8	1.2	4.0	6.2	2.3	11.2	4.5	1.7	12.0	4.8
Skeletonema			0.7	3.3	14.9	7.3			20.5	1.6	4.8
Surirella		0.4	1.3	<0.1			11.2	0.9	0.3	0.1	1.4
Synedra	1.0	0.4									0.1
Thalassionema		0.9		<0.1	1.0	0.4					0.2

Thalassiosira				3.7	6.6	2.1		13.6	1.3		2.7
Thalassiothrix			2.4	<0.1	<0.1	0.4				1.5	0.4
Torodinium									0.6		<0.1
Trachyneis			0.1			0.4	10.2				1.1
Triceratium					<0.1						<0.1
Trichodesmium			1.2	<0.1	<0.1		1.0			1.5	0.4
Tropidoneis						0.2		4.5			0.5
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 4.6.6: Comparative account of phytoplankton biomass, population, chlorophyll :pehophytin ratio, population and total genera with earlier observations.

Zone	Biomass ($mg\ m^3$)			Pheophytin ($mg\ m^3$)			Chlorophyll : Pheophytin Ratio			Population (no x 10^3 Cells L^{-1})			Total genera (no)		
	Min	Max	Av	Min	Max	Av	Min	Max	Av	Min	Max	Av	Min	Max	Av
Premonsoon (March 2007)															
Coastal water (St J1 to J3)	0.2	0.9	0.5	0.4	3.8	1.8	0.2	3.8	1.3	23.2	83.2	43.5	18	24	21
Lower estuary (St J4 and J5)	0.2	1.3	0.5	0.5	6.6	3.5	0.2	6.6	3.5	43.2	142.4	75.6	14	25	21
Upper estuary (St J6)	3.0	4.7	3.6	3.0	4.7	3.9	3.0	4.7	3.8	116.0	134.4	125.2	28	28	28
Offshore (J7)	No Collection														
FSRU Site (St J9&J10)	No Collection														
Postmonsoon (December 2007)															
Coastal water (St J1 to J3)	0.3	0.3	1.4	0.1	0.7	0.3	0.1	1.4	0.5	7.2	68.8	36.9	9	19	14
Lower estuary (St J4 and J5)	0.7	1.9	1.1	0.01	0.5	0.3	0.01	1.9	0.8	10.4	38.4	26.2	11	14	13
Upper estuary(St J6)	1.2	1.6	1.4	0.1	0.2	0.1	0.1	1.6	0.8	28.8	34.4	31.6	12	14	13
Offshore (J7)	No Collection														
FSRU Site (StJ9&J10)	No Collection														
Postmonsoon (January 2016)															
Coastal water (St J1, J2, J3, J8)	0.1	1.1	0.7	0.03	0.7	0.1	0.8	18.9	8.6	6.6	26.2	13.3	5	8	6
Lower estuary (St J4 and J5)	0.2	2.0	1.3	0.1	2.5	0.4	0.1	9.7	4.7	10.8	34.6	20.73	5	10	7
Upper estuary(St J6)	1.1	2.2	1.7	0.4	0.7	0.6	2.4	3.0	2.7	12.8	39	25.45	7	9	8

Offshore (St J7)	No Collection														
FSRU Site (J9&J10)	No Collection														
Premonsoon (March 2016)															
Coastal water (St J1, J2, J3, J8)	0.45	1.73	1.18	0.3	0.69	0.39	2.75	3.63	3.03	8.4	17.2	12.8	6	10	8
Lower estuary (Sts J4 and J5)	1.52	3.1	2.39	0.14	0.69	0.43	3.32	13.82	6.05	22.6	52.8	37.7	8	16	12
Upper estuary (St J6)	1.9	3.05	2.31	0.32	0.58	0.47	4.4	5.6	5.0	35.2	96.4	64.7	14	16	15
Offshore (J7)	No Collection														
FSRU Site (J9&J10)	No Collection														
Premonsoon (March 2017)															
Coastal water (Sts J1, J2, J3, J8)	0.43	3.13	0.98	0.01	0.75	0.25	2.59	5.19	4.02	8.2	51.4	27.34	7	14	10.5
Lower estuary (Sts J4 and J5)	2.08	4.69	3.08	0.36	3.02	1.15	1.52	5.53	3.15	89	409.6	249.3	12	20	16.5
Upper estuary(St J6)	2.83	5.05	3.67	0.68	1.56	0.96	2.64	5.48	4.06	132.4	470	301.2	17	23	20
Offshore (J7)	0.33	1.06	0.70	0.02	0.75	0.34	1.81	2.27	2.04	8.8	10.8	9.8	7	9	8
FSRU Site (J9&J10)	0.82	3.42	1.57	0.36	1.6	0.70	1.55	2.96	2.28	43	219.8	131.4	14	17	15.8

Table 4.6.7: Distribution of Zooplankton off Jaigarh during March 2017.

Station (Date)	Time(h)/Tide	Biomass (ml/100m^3)	Population (nox10^3/100m^3)	Total Groups (no)	Major group (%)
J1 (1) (04/03/2017)	0800 (Fl-Eb)	29.0	219.7	19	Copepods (87.8), siphonophores (3.5), lamellibranchs (2.8), chaetognaths (1.4), decapod larvae (1.1), gastropods (1.1), *lucifer* sp. (0.8), cladocerans (0.8), appendicularians (0.4), fish eggs (0.1) , other (0.1).
J1(2)	0810 (Fl-Eb)	49.0	40.0	16	Copepods (78.1), siphonophores (12.9), chaetognaths (4.4), cladocerans (1.2), decapod larvae (1.1), polychaetes (0.8) , lamellibranchs (0.6), pteropods (0.4), Amphipods(0.1) appendicularians (0.1), gastropods (0.1), other (0.1)
J2 (1) (04/03/2017)	0835 (Fl-Eb)	11.6	22.5	16	Copepods (86.1), chaetognaths (4.0), siphonophores (4.0), decapod larvae (2.6), cladocerans(1.6), lamellibranchs (1.3), amphipods(0.1), ctenophores (0.1), pteropods (0.1), other (0.1)
J2(2)	0845 (Fl-Eb)	36.8	214.6	21	Copepods (87.3), siphonophores (3.2), chaetognaths (2.6), cladocerans(2.1), decapod larvae (2.0), pteropods (1.1), lamellibranchs (1.0), gastropods (0.3), *lucifer* sp. (0.1), appendicularians (0.1),

					other (0.1
J3 (1) (04/03/2017)	0910 (F.Ebb)	25.5	45.2	16	Copepods (83.4), siphonophores (6.6), decapod larvae (2.9), chaetognaths (2.2), lamellibranchs (1.8), *lucifer* sp. (1.2), pteropods (1.2), cladocerans(0.4), amphipods(0.1), gastropods (0.1), other (0.1)
2	1545 (F.Fl)	5.4	34.0	18	Copepods (86.3), *lucifer* sp. (4.2), lamellibranchs (2.8), siphonophores (2.2), decapod larvae (1.9), cladocerans(0.9), pteropods (0.9), chaetognaths (0.3), gastropods (0.2), polychaetes (0.1) , other (0.1)
J4(1) (05/03/2017)	0645 (Fld-Eb)	2.2	17.9	17	Copepods (80.4), decapod larvae (8.9), lamellibranchs (4.1), fish eggs (1.6) , chaetognaths (1.5), siphonophores (1.4), *lucifer* sp. (1.0), gastropods (0.3), Amphipods(0.1), Stomatopods(0.1) cladocerans(0.1), foraminiferans (0.1) , pteropods (0.1), polychaetes (0.1) , other (0.1)
2	0845 (Fld-Eb)	5.2	24.0	16	Copepods (78.8), decapod larvae (10.8), fish eggs (3.2) , lamellibranchs (2.3), gastropods (1.5), *lucifer* sp. (1.0), siphonophores (0.9), chaetognaths (0.6),

					cladocerans(0.3), appendicularians (0.2), Fish Larvae(0.1), Stomatopods(0.1) pteropods (0.1), other (0.1)
3	1000 (F.Eb)	3.8	43.9	17	Copepods (89.0), decapod larvae (4.5), chaetognaths (1.6), siphonophores (1.6), fish eggs (1.4) , *lucifer* sp. (1.0), lamellibranchs (0.4), cladocerans(0.3), other (0.1)
4	1045 (Eb-Fld)	13.3	102.5	21	Copepods (77.4), decapod larvae (11.2), *lucifer* sp. (3.6), siphonophores (1.5), gastropods (1.4), lamellibranchs (1.2), chaetognaths (1.2), cladocerans(1.0), fish eggs (0.7) , appendicularians (0.3), foraminiferans (0.3) , other (0.1)
5	1245 (Eb-Fld)	15.5	160.3	20	Copepods (80.9), decapod larvae (7.1), *lucifer* sp. (4.0), lamellibranchs (1.5), chaetognaths (1.2), siphonophores (1.2), gastropods (1.2), appendicularians (1.0), cladocerans(1.0), fish eggs (0.6) , pteropods (0.1), polychaetes (0.1) , other (0.1)
6	1445 (Eb-Fld)	4.5	34.2	15	Copepods (91.4), *lucifer* sp. (4.5), chaetognaths (2.0), siphonophores (1.2), Amphipods(0.2), fish eggs (0.2) , lamellibranchs (0.1), cladocerans(0.1),

					pteropods (0.1), polychaetes (0.1) , other (0.1)
7	1645 (F.Fld)	15.6	142.2	19	Copepods (73.7), *lucifer* sp. (10.1), decapod larvae (7.8), lamellibranchs (3.6), cladocerans(1.9), chaetognaths (1.0), siphonophores (0.6), fish eggs (0.6) , gastropods (0.6), other (0.1)
8	1845 (Fld-Eb)	10.1	29.7	16	Copepods (67.4), *lucifer* sp. (17.3), lamellibranchs (7.3), decapod larvae (5.9), chaetognaths (1.4), fish eggs (0.2) , Amphipods(0.1), cladocerans(0.1), gastropods (0.1), polychaetes (0.1) , other (0.1)
J5(1) (05/03/2017)	1000 (F.Eb)	43.9	56.8	16	Copepods (95.8), decapod larvae (3.4), medusae(0.3), *lucifer* sp. (0.1), fish eggs (0.1) , gastropods (0.1), other (0.1)
2	1700 (F.Fld)	10.2	78.8	18	Copepods (66.3), decapod larvae (15.2), *lucifer* sp. (10.5), lamellibranchs (3.1), cladocerans(1.3), gastropods (1.1), chaetognaths (1.0), siphonophores (0.7), fish eggs (0.5) , appendicularians (0.1), Amphipods(0.1), other (0.1)
J6(1) (05/03/2017)	0930 (F.Eb)	12.5	32.5	17	Copepods (90.8), decapod larvae (3.5), fish eggs (2.8) , lamellibranchs (1.4),

					pteropods (0.6), medusae(0.3), Fish Larvae(0.1), Amphipods(0.1), ctenophores (0.1), gastropods (0.1), other (0.1)
2	1715 (F.Fld)	7.2	27.8	15	Copepods (88.9), decapod larvae (4.2), *lucifer* sp. (3.5), chaetognaths (1.8), cladocerans(0.6), pteropods (0.5), Amphipods(0.2), Fish Larvae(0.1), fish eggs (0.1) , other (0.1)
J7(1) (02/03/2017)	1630 (Fl-Eb)	37.5	100.1	16	Copepods (83.5), siphonophores (3.9), appendicularians (3.1), lamellibranchs (3.0), cladocerans(2.1), gastropods (1.8), chaetognaths (0.6), decapod larvae (0.6), pteropods (0.6), ctenophores (0.4), polychaetes (0.3) , other (0.1)
2	1650 (Fl-Eb)	29.9	53.0	19	Copepods (77.7), siphonophores (7.0), appendicularians (3.4), lamellibranchs (3.4), gastropods (2.7), cladocerans(2.0), chaetognaths (1.3), pteropods (1.1), decapod larvae (0.6), polychaetes (0.3) , ctenophores (0.2), Amphipods(0.1), Stomatopods(0.1) other (0.1)
J8(1) (2/03/2017)	1500 (Fl-Eb)	26.5	84.4	16	Copepods (90.5), siphonophores (5.4), lamellibranchs (1.7), cladocerans(0.9), appendicularians (0.6),

					chaetognaths (0.3), decapod larvae (0.3), gastropods (0.2), other (0.1)
2	1515 (Fl-Eb)	79.6	374.2	16	Copepods (92.1), siphonophores (2.7), lamellibranchs (2.3), cladocerans(0.8), chaetognaths (0.7), appendicularians (0.6), gastropods (0.4), decapod larvae (0.2), other (0.1)
J9(1) (3/3/2017)	700 (Fl-Eb)	14.8	22.7	15	Copepods (83.8), decapod larvae (5.9), lamellibranchs (2.7), siphonophores (2.3), chaetognaths (1.7), pteropods (1.6), cladocerans(1.2), *lucifer* sp. (0.4), Amphipods(0.1), ctenophores (0.1), fish eggs (0.1) , other (0.1)
2	800 (F.Eb)	15.4	105.9	21	Copepods (85.2), decapod larvae (4.5), siphonophores (3.0), lamellibranchs (2.4), *lucifer* sp. (1.8), cladocerans(1.4), chaetognaths (1.0), gastropods (0.4), fish eggs (0.1) , other (0.1)
3	900 (Eb-Fl)	20.9	201.4	19	Copepods (92.2), lamellibranchs (2.0), siphonophores (2.0), cladocerans(1.5), *lucifer* sp. (1.1), chaetognaths (0.4), pteropods (0.3), gastropods (0.3), fish eggs (0.1) , other (0.1)
4	1100 (Eb-Fl)	12.9	65.9	16	Copepods (92.3), siphonophores (2.5), lamellibranchs (1.2),

					chaetognaths (1.2), *lucifer* sp. (1.0), decapod larvae (0.8), cladocerans(0.7), Amphipods(0.1), pteropods (0.1), other (0.1)
5	1300 (Eb-Fl)	31.6	69.6	18	Copepods (82.1), siphonophores (9.2), lamellibranchs (2.1), pteropods (1.9), chaetognaths (1.5), decapod larvae (1.2), *lucifer* sp. (1.1), cladocerans(0.6), Amphipods(0.1), gastropods (0.1), other (0.1)
6	1500 (F.Fld)	9.5	40.5	16	Copepods (82.9), lamellibranchs (6.3), chaetognaths (2.6), siphonophores (2.6), *lucifer* sp. (2.3), decapod larvae (2.3), cladocerans(0.7), Amphipods(0.1), pteropods (0.1), other (0.1)
7	1700 (Fld-Eb)	14.6	27.5	18	Copepods (88.2), *lucifer* sp. (3.2), lamellibranchs (2.8), chaetognaths (2.4), decapod larvae (1.1), siphonophores (0.9), cladocerans(0.9), Amphipods(0.1), pteropods (0.1), gastropods (0.1), polychaetes (0.1) , other (0.1)
J10(1) (06/03/2017)	1030 (Eb-Fld)	8.1	106.8	14	Copepods (87.7), decapod larvae (3.1), *lucifer* sp. (2.4), lamellibranchs (2.3), siphonophores (1.4), cladocerans(1.4), chaetognaths (0.9),

					gastropods (0.4), fish eggs (0.1) , pteropods (0.1), polychaetes (0.1) , other (0.1)
2	1045 (Eb-Fld)	2.8	33.2	19	Copepods (78.1), decapod larvae (7.6), *lucifer* sp. (5.6), lamellibranchs (4.5), siphonophores (1.5), cladocerans(0.9), chaetognaths (0.7), fish eggs (0.6) , polychaetes (0.2) , Fish Larvae(0.1), ctenophores (0.1), other (0.1)

Table 4.6.8: Range and average (parenthesis) of zooplankton at different stations Jaigarh during March 2017.

Station (Date)	Biomass ($ml/100m^3$)	Population ($nox10^3/100m^3$)	Total Groups (no)	Major group (%)
J1 (04/03/2017)	29.0-49.0 (39.0)	40.0-219.7 (129.9)	16-19 (18)	Copepods (86.3), decapod larvae (54.90), siphonophores (4.9), lamellibranchs (2.5), chaetognaths (1.9), gastropods (1.0), cladocerans(0.8), *lucifer* sp.(0.7), appendicularians (0.3), polychaetes (0.2) , fish eggs (0.1) , pteropods (0.1), other (0.1)
J2 (04/03/2017)	11.6-36.8 (24.2)	22.5-214.6 (118.5)	16-21 (19)	Copepods (87.2), siphonophores (3.3), chaetognaths (2.8), decapod larvae (2.1), cladocerans(2.0), lamellibranchs (1.0), pteropods (1.0), gastropods (0.3), appendicularians (0.1), other (0.1)
J3 (04/03/2017)	5.4-25.5 (15.5)	34.0-45.2 (39.6)	16-18 (17)	Copepods (84.6), siphonophores (4.7), *lucifer* sp.(2.5), decapod larvae (2.5), lamellibranchs (2.2), chaetognaths (1.4), pteropods (1.1), cladocerans(0.6), gastropods (0.1), polychaetes (0.1) , other (0.1)
J4 (05/03/2017)	2.2-15.6 (8.8)	17.9-160.3 (69.3)	15-20 (17)	Copepods (78.9), decapod larvae (7.5), *lucifer* sp.(5.8), lamellibranchs (2.3), chaetognaths (1.2), siphonophores (1.1), cladocerans(1.0),

				gastropods (0.9), fish eggs (0.8) , appendicularians (0.4), foraminiferans (0.1) , other (0.1)
J5 (05/03/2017)	10.2-43.9 (27.1)	56.8-78.8 (67.8)	16-18 (17)	Copepods (78.6), decapod larvae (10.2), *lucifer* sp.(6.2), lamellibranchs (1.8), chaetognaths (0.6), gastropods (0.6), siphonophores (0.4), fish eggs (0.4) , medusae(0.1), other (0.1)
J6 (05/03/2017)	7.2-12.5 (9.9)	27.8-32.5 (30.1)	15-17 (16)	Copepods (89.9), decapod larvae (3.9), *lucifer* sp.(1.7), fish eggs (1.6) , lamellibranchs (0.8), chaetognaths (0.8), pteropods (0.5), cladocerans (0.3), medusae(0.2), ctenophores (0.1), gastropods (0.1), other (0.1)
J7 (02/03/2017)	29.9-37.5 (33.7)	53.0-100.1 (76.5)	16-19 (18)	Copepods (81.4), siphonophores (5.0), appendicularians (3.3), lamellibranchs (3.1), cladocerans(2.1), gastropods (2.1), chaetognaths (0.8), pteropods (0.8), decapod larvae (0.6), ctenophores (0.3), polychaetes (0.3) , other (0.1)
J8 (02/03/2017)	26.5-79.6 (53.1)	84.4-374.2 (229.3)	16	Copepods (91.8), siphonophores (3.2), lamellibranchs (2.2), cladocerans(0.9), appendicularians (0.6), chaetognaths (0.6), gastropods (0.4), decapod larvae (0.3),

				other (0.1)
J9 (03/03/2017)	9.5-31.6 (17.1)	22.7-201.4 (76.2)	15-19 (18)	Copepods (88.2), siphonophores (3.2), lamellibranchs (2.4), decapod larvae (1.6), *lucifer* sp.(1.4), chaetognaths (1.1), cladocerans (1.1), pteropods (0.5), gastropods (0.2), fish eggs (0.1) , other (0.1)
J10 (06/03/2017)	2.8-8.1 (5.5)	33.2-106.8 (70.0)	14-19 (17)	Copepods (85.5), decapod larvae (4.2), *lucifer* sp.(3.2), lamellibranchs (2.9), siphonophores (1.5), cladocerans(1.3), chaetognaths (0.8), gastropods (0.3), fish eggs (0.2) , polychaetes (0.1) , other (0.1)

Table 4.6.9: Percentage composition of Zooplanktons of Jaigarh during March 2017

Faunal Groups	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	% composition
Foraminiferans	<0.1	<0.1	-	0.1	-	<0.1	-	<0.1	<0.1	<0.1	<0.1
Siphonophores	4.9	3.3	4.7	1.1	0.4	-	5.0	3.2	3.2	1.5	3.1
Medusae	<0.1	<0.1	<0.1	<0.1	0.1	0.2	<0.1	-	<0.1	<0.1	<0.1
Ctenophores	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.3	<0.1	<0.1	<0.1	<0.1
Chaetognaths	1.9	2.8	1.4	1.2	0.6	0.8	0.8	0.6	1.1	0.8	1.2
Polychaetes	0.2	<0.1	0.1	<0.1	<0.1	<0.1	0.3	0.1	<0.1	0.1	0.1
Cladocerans	0.8	2.0	0.6	1.0	0.8	0.3	2.1	0.9	1.1	1.3	1.1
Copepods	86.3	87.2	84.6	78.9	78.6	89.9	81.4	91.8	88.2	85.5	86.4
Amphipods	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Lucifer sp.	0.7	-	2.5	5.8	6.2	1.7	<0.1	<0.1	1.4	3.2	1.5
Decapod larvae	1.1	2.1	2.5	7.5	10.2	3.9	0.6	0.3	1.6	4.2	2.6
Stomatopods	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	-	<0.1	<0.1	<0.1
Heteropods	-	-	<0.1	-	-	<0.1	<0.1	<0.1	<0.1	-	<0.1
Pteropods	0.1	1.0	1.1	<0.1	<0.1	0.5	0.8	<0.1	0.5	<0.1	0.3
Gastropods	1.0	0.3	0.1	0.9	0.6	0.1	2.1	0.4	0.2	0.3	0.6
Lamellibranchs	2.5	1.0	2.2	2.3	1.8	0.8	3.1	2.2	2.4	2.9	2.2
Appendicularians	0.3	0.1	-	0.4	<0.1	-	3.3	0.6	<0.1	-	0.5
Doliolids	-	-	-	<0.1	<0.1	-	<0.1	-	<0.1	<0.1	<0.1
Salpids	-	<0.1	-	<0.1	-	-	<0.1	<0.1	<0.1	-	<0.1
Fish Eggs	0.1	<0.1	<0.1	0.8	0.4	1.6	0.02	0.01	0.1	0.2	0.2
Fish Larvae	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Isopods	-	<0.1	-	<0.1	-	<0.1	-	-	<0.1	<0.1	<0.1

Table 4.6.10: Abundance of zooplanktons of Jaigarh during March 2017

Faunal Groups	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	% composition
Foraminiferans	+	+	-	+	-	+	-	+	+	+	+
Siphonophores	+	+	+	+	+	-	+	+	+	+	+
Medusae	+	+	+	+	+	+	+	-	+	+	+
Ctenophores	+	+	+	+	+	+	+	+	+	+	+
Chaetognaths	+	+	+	+	+	+	+	+	+	+	+
Polychaetes	+	+	+	+	+	+	+	+	+	+	+
Cladocerans	+	+	+	+	+	+	+	+	+	+	+
Copepods	+	+	+	+	+	+	+	+	+	+	+
Amphipods	+	+	+	+	+	+	+	+	+	+	+
Lucifer sp.	+	-	+	+	+	+	+	+	+	+	+
Decapod larvae	+	+	+	+	+	+	+	+	+	+	+
Stomatopods	-	-	+	+	+	+	+	-	+	+	+
Heteropods	-	-	+	-	-	+	+	+	+	-	+
Pteropods	+	+	+	+	+	+	+	+	+	+	+
Gastropods	+	+	+	+	+	+	+	+	+	+	+
Lamellibranchs	+	+	+	+	+	+	+	+	+	+	+
Appendicularians	+	+	-	+	+	-	+	+	+	-	+
Doliolids	-	-	-	+	+	-	+	-	+	+	+
Salpids	-	+	-	+	-	-	+	+	+	-	+
Fish Eggs	+	+	+	+	+	+	+	+	+	+	+
Fish Larvae	+	+	+	+	+	+	+	+	+	+	+
Isopods	-	+	-	+	-	+	-	-	+	+	+

Table 4.6.11: Comparative account of Zooplankton biomass, population and total group

Zone	Biomass ($ml/100m^3$)			Population (no x $10^3/100m^3$)			Total groups (no)		
	Min	Max	Av	Min	Max	Av	Min	Max	Av
Pre monsoon (March 2007)									
Coastal water (Sts J1 to J3)	3.7	4.9	4.23	82.6	135.8	108.77	14	16	15
Lower estuary (Sts J4 and J5)	1.8	6.6	4.2	72.6	79.2	75.9	15	16	15.5
Upper estuary (St J6)	6.7	13.3	10	103.4	196.3	150	16	16	16
Offshore (J7)	No Collection								
FSRU Site (J9&J10)	No Collection								
Post monsoon (December 2007)									
Coastal water (StsJ1 to J3)	2.2	15.2	7.9	18.5	40	32.7	18	22	19.7
Lower estuary (StsJ4 and J5)	1.7	2.7	2.2	19.3	38.1	28.7	11	15	13
Upper estuary (St J6)	0.3	6.9	3.6	1.3	18.2	9.8	11	11	11
Offshore (J7)	No Collection								
FSRU Site (J9&J10)	No Collection								
Post monsoon (January 2016)									
Coastal water (StsJ1 to J3)	0.7	3.6	1.9	8.8	50.1	23.9	10	13	12
Lower estuary (StsJ4 and J5)	0.2	1.2	0.4	3.3	20.1	11.7	8	12	10
Upper estuary (St J6)	0.1	0.2	0.2	4.6	8.7	6.7	8	9	9
Offshore (J7)	No Collection								
FSRU Site (J9&J10)	No Collection								
Pre monsoon (March 2016)									
Coastal water (Sts J1 to J3)	2.4	5.3	3.2	27.4	49.1	34.3	8	14	11
Lower estuary (Sts J4 and J5)	0.5	1.4	1.0	3.9	20.9	10.7	8	15	11
Upper estuary (St J6)	0.9	1.1	1.0	6.7	12.2	9.4	8	10	9
Offshore (J7)	No Collection								
FSRU Site (J9&J10)	No Collection								
Pre monsoon (March 2017)									
Coastal water (Sts J1, J2, J3, J8)	5.4	79.6	32.9	22.5	374.2	129.3	16	21	18
Lower estuary (Sts J4 and J5)	2.2	43.9	18.0	17.9	160.3	68.5	15	20	17
Upper estuary (St J6)	7.2	12.5	9.9	27.8	32.5	30.1	15	17	16
Offshore (J7)	9.5	31.6	17.1	22.7	201.4	76.2	15	19	18
FSRU Site (J9&J10)	2.8	37.5	19.6	33.2	106.8	73.3	14	19	18

with earlier observations

Table 4.6.12: Range and average (parenthesis) of subtidal macrobenthos at different stations of Jaigarh during March 2017

Station	Date	Biomass (Wet wt.;g/m^2)	Population (No./m^2)	Faunal Group (No.)	Major Group
J1	04/03/17	6.9-13.6 (10.1)	3175-5475 (4113)	3-8 (6)	Polychaetes, amphipods
J2	04/03/17	1.9-3.4 (2.6)	1000-2250 (1600)	3-5 (4)	Polychaetes, amphipods
J3	04/03/17	1.8-8.0 (4.9)	825-3250 (1900)	2-4 (4)	Polychaetes
J4	04/03/17	13.4-40.0 (26.6)	1950-6175 (3744)	2-8 (5)	Polychaetes, amphipods
J5	05/03/17	17.2-42.3 (28.7)	2375-10125 (6794)	5-6 (5)	Polychaetes
J6	05/03/17	4.9-9.9 (7.5)	1100-1900 (1525)	6-9 (7)	Polychaetes
J7	02/03/17	6.2-46.0 (18.1)	1425-2575 (1919)	3-7 (5)	Polychaetes
J8	02/03/17	0.7-6.9 (3.0)	425-1800 (1106)	1-3 (2)	Polychaetes
J9	03/03/17	0.03-0.6 (0.2)	25-100 (63)	1-2 (1)	Polychaetes
J10	06/03/17	0.06-0.4 (0.2)	75-250 (138)	1-2 (2)	Polychaetes
OVERALL AVERAGE	06/03/17	0.03-46.0 (10.2)	25-10125 (2290)	1-9 (4)	Polychaetes

Table 4.6.13: Composition (%) of subtidal macrobenthos in coastal water of Jaigarh during March 2017

Faunal Groups	Stations										
	J1	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**	**J9**	**J10**	**Avg.**
Phylum Cnidaria											
Anthozoans					0.1	0.4					0.05
Phylum Platyhelminthes											
Turbellarians						0.4	0.3				0.05
Phylum Nemertea											
Nemerteans						0.4					0.03
Phylum Phoronida											
Phoronids	0.3	0.4	1.3		0.4	2.5					0.47
Phylum Mollusca											
Gastropods	0.5						0.3				0.11
Pelecypods	2.3	0.8			0.1	3.7	2				0.90
Phylum Annelida											
Polychaetes	74.8	78.1	92.4	78.3	95.9	77.9	89.6	95.5	90	90.9	85.89
Phylum Sipuncula											
Sipunculids	0.8	1.2	1.6	2	0.6	4.9	1.3	0.6			1.31
Phylum Echiurida											
Echiurids				0.2							0.03
Phylum Arthropoda											
Amphipods	18.4	16	3.3	11	1.4	3.3	4.6	2.8			7.65
Anomurans	0.2										0.03
Brachyurans				5.7	1.1			0.6			1.28
Penaeid shrimps				0.3	0.1	0.8					0.14
Cumaceans	0.8						0.7				0.19
Decapod larvae						0.4	0.3	0.6	10		0.10
Ostracods							0.7				0.06
Mysids			0.3	0.5	0.2						0.17
Stomatopods				0.2	0.1	0.4					0.08
Sergestids			1							9.1	0.14
Tanaids	0.8	3.1		1.8	0.1						0.68
Phylum Echinodermata											
Ophiuroids	1.4	0.4			0.1	4.9					0.62
Phylum Chordata											
Fish Larvae							0.3				0.03

Table 4.6.14: Comparative account of Macrobenthos biomass, population and total group with earlier observations.

Zone	Biomass (Wet wt.;g/m^2)			Population (No./m^2)			Total groups (no.)		
	Min	Max	Av	Min	Max	Av	Min	Max	Av
Pre monsoon (March 2007)									
Coastal water (Sts J1 to J3)	5	9.4	6.54	706	3700	2220.7	5	7	5.7
Lower estuary (Sts J4 and J5)	2.02	2.43	2.23	1588	1638	1613	5	6	5.5
Upper estuary(St J6)	4.47	11.79	7.25	2650	3925	3294	3	8	6
Offshore (J7)	No Collection								
FSRU Site (J9&J10)	No Collection								
Post monsoon (December 2007)									
Coastal water (StsJ1 to J3)	2.13	4.91	3.78	1101	2718	1683.66	4	6	5
Lower estuary (StsJ4 and J5)	6.82	59.91	33.37	1570	10120	5845	4	9	6.5
Upper estuary(St J6)	2.62	4.23	3.45	500	2600	1107	2	5	4
Offshore (J7)	No Collection								
FSRU Site (J9&J10)	No Collection								
Post monsoon January 2016									
Coastal water (StsJ1 to J3)	1.40	10.80	5.10	875	4350	2261	4	5	5
Lower estuary (StsJ4 and J5)	3.00	15.10	6.40	900	3075	1972	2	4	4
Upper estuary(St J6)	0.40	2.20	1.00	175	250	200	2	4	3
Offshore (J7)	No Collection								
FSRU Site (J9&J10)	No Collection								
Premonsoon March 2016									
Coastal water (Sts J1 to J3)	2.80	20.00	9.80	1300	13175	4765	3	7	5
Lower estuary (Sts J4 and J5)	7.40	105.00	32.45	3200	7275	4676	5	7	6
Upper estuary(St J6)	0.70	3.20	1.90	200	600	419	4	5	5
Offshore (J7)	No Collection								
FSRU Site (J9&J10)	No Collection								
Premonsoon March 2017									
Coastal water (Sts J1, J2, J3, J8)	2.6	10.1	5.15	1106	4113	2179.75	3	8	5
Lower estuary (Sts J4 and J5)	26.6	28.7	27.65	3744	6794	5269	6	8	7
Upper estuary(St J6)	4.9	9.9	7.5	1100	1900	1525	6	9	7
Offshore (J7)	0.03	0.6	0.2	25	100	63	1	2	1
FSRU Site (J9&J10)	0.2	18.1	9.15	138	1919	1028.5	2	5	3.5

Table 4.6.15: Station-wise distribution of meiofaunal parameters in Jaigarh during March 2017

Stations	Biomass (µg/10cm²)			Population (Ind./ 10cm²)			Total groups (No.)		
	Min	Max	Average	Min	Max	Average	Min	Max	Average
March 2017 (Pre-monsoon)									
J1	40.49	547.17	212.01	89	457	253	2	6	4
J2	323.39	1428.00	872.80	318	1089	760	4	11	8
J3	7.53	292.66	181.66	40	643	288	3	5	4
J4	6.30	212.56	101.70	24	521	216	2	4	3
J5	9.91	861.45	436.97	14	502	318	2	10	6
J6	14.07	129.77	90.25	7	245	114	1	7	4
J7	264.82	647.54	436.04	485	548	519	4	6	5
J8	144.66	188.73	170.45	253	510	344	1	2	2
J9	1.79	2.87	2.33	3	24	17	1	3	2
J10	1.55	4.27	2.91	3	21	15	1	3	2

Table 4.6.16: Composition (%) of subtidal meiobenthos in coastal water of Jaigarh during March 2017

Station	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	Group avg.
Amphipoda	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Bivalvia	0.00	0.00	0.00	0.00	1.66	0.00	0.45	0.00	0.00	0.00	0.32
Ciliophora	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.08
Cladocera	0.00	0.00	0.00	0.00	0.10	0.00	0.09	0.00	0.00	0.00	0.03
Copepoda	0.00	3.81	0.00	4.88	7.67	14.52	1.36	0.00	0.00	0.00	3.16
Echiura	0.00	0.33	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.15
Foraminifera	6.68	6.96	8.81	2.79	1.66	2.69	3.64	0.82	14.29	31.25	4.74
Gastropoda	0.19	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
Halacaroida	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Insecta	0.00	0.00	0.00	0.00	1.14	0.00	0.00	0.00	0.00	0.00	0.17
Kinorhyncha	0.00	1.38	1.38	0.00	0.00	0.00	1.82	0.00	0.00	0.00	0.79
Nauplius	0.00	1.05	0.00	0.00	0.52	2.69	0.45	0.00	0.00	0.00	0.47
Nematoda	90.84	77.41	85.41	90.79	80.21	62.37	91.82	99.18	77.14	46.88	85.53
Nemertina	0.00	0.00	0.00	0.00	2.18	0.54	0.00	0.00	0.00	0.00	0.33
Ostracoda	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Polychaeta	1.15	4.73	2.01	0.00	3.21	2.69	0.00	0.00	0.00	0.00	1.97
Tanaidacea	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Unidentified	0.00	3.35	2.39	0.84	1.14	14.52	0.36	0.00	8.57	21.88	1.94
Total	100	100	100	100	100	100	100	100	100	100	100

Table 4.6.17: District wise estimated marine fish production of Maharashtra state

In Tonne

Sr. No.	District	FINANCIAL YEAR (APRIL TO MARCH)				
		2011-11	2011-12	2012-13	2013-14	2014-15
1	2	3	4	5	6	7
1	Thane	137701 (30.8)	117972 (27.2)	123792 (27.7)	120924 (25.9)	104700 (22.5)
2	Mumbai suburban	143157 (32.0)	1555799 (35.9)	70227 (15.6)	70826 (15.2)	66077 (14.3)
3	Mumbai city			98471 (21.9)	98748 (21.1)	114957 (24.8)
4	Raigad	46919 (10.5)	46912 (10.8)	41984 (9.4)	42825 (9.2)	41249 (8.9)
5	Ratnagiri	95590 (21.4)	88438 (20.4)	87690 (19.5)	106852 (22.8)	115042 (24.9)
6	sindhudurg	23336 (5.3)	24563 (5.7)	26749 (5.9)	27283 (5.8)	21560 (4.6)
STATE TOTAL		446703 (100.0)	433684 (100.0)	448913 (100.0)	467458 (100.0)	463585 (100.0)

Note- Figures in bracket shows the percentage share of district Production to the state production.

Table 4.6.18: Variety wise marine fish production of Maharashtra state

(In Tonne)

Sr. No.	Variety	Financial year (APRIL TO MARCH)				
		2010-11	2011-12	2012-13	2013-14	2014-15
1	2	3	4	5	6	7
1	Elasmobranchs	6693	8726	7334	6311	6126
2	Eels	1304	1018	2917	2614	1284
3	catfishes	13449	14327	15604	13345	15876
4	Chirocentrus sp.	2840	2810	2428	3815	3036
5	Sardine	39529	56740	49769	55182	67132
6	Hilsa ilisha	1278	1649	1545	2865	1762
7	Anchovies	17734	20681	18724	20363	20591
8	Thrissocies	5648	6970	7034	5789	7799
9	Other Clupieds	339	1154	2374	2044	1617
10	Harpodon nehereus	62996	51190	81327	71213	50965
11	Perches	409	476	272	268	286
12	Redsnapper	679	535	664	473	359
13	Polynemidae	1049	1720	1658	870	2668
14	Sciaenids	6323	7614	6311	5057	7697
15	Otolithoides sp	17978	17251	17374	23381	20245
16	Trichiuridae (Ribbonfishes)	23834	24094	27329	21561	20143
17	Caranx	14959	7210	5441	7291	2576
18	Pomfrets	11411	9919	10468	11391	12872
19	Black pomfret (Formio niger)	1741	1260	1153	1548	2100
20	Mackerals(Rastraligs karagurta)	40749	31118	12802	19947	15094
21	Seerfishes	8238	8696	8119	8926	10365
22	Tunnies	4897	3965	3016	3165	3587
23	BregmacerosMacelendi	222	557	1116	221	872
24	Soles(flat fishs)	4713	7437	6196	8237	9404
25	Sphyraene sp(Baracudas)	2736	1821	1554	2054	1048
26	Leiognathus sp	1225	808	803	806	997
27	Upeneus sp.	11175	9411	14413	13272	13050
28	Penaeid Prawns	35137	37561	42297	46440	47902
29	Non-penaeid Prawns	69110	63186	55964	61799	55493
30	Natantion Decapods (Lobsters)	474	288	788	375	378
31	Laetarius	2649	2261	2778	2744	3282
32	Loligoduvaucelli(Cephalopoda)	15540	11223	16636	18345	26305
33	Miscellaneous	19645	20008	22705	25746	30675
	TOTAL	446703	433684	448913	467458	463585

Table 4.6.19: Variety wise marine fish production of Ratnagiri district

(In Tonne)

Sr. No.	Variety	Financial year (APRIL TO MARCH)				
		2010-11	2011-12	2012-13	2013-14	2014-15
1	2	3	4	5	6	7
1	Elasmobranchs	81	58	227	122	101
2	Eels	2	2	110	30	122
3	catfishes	2051	791	2667	1177	589
4	Chirocentrus sp.	71	89	314	163	186
5	Sardine	29141	32699	31645	39927	47914
6	Hilsa ilisha	8	5	21	845	30
7	Anchovies	116	146	288	318	633
8	Thrissocies	51	325	332	40	272
9	Other Clupieds	76	847	2257	640	645
10	Harpodon nehereus	87	0	33	188	161
11	Perches	93	0	32	3	0
12	Redsnapper	5	0	31	26	15
13	Polynemidae	4	10	1	34	26
14	Sciaenids	47	52	107	93	449
15	Otolithoides sp	3249	2802	2703	7020	3605
16	Trichiuridae (Ribbonfishes)	3286	4362	7840	3334	5783
17	Caranx	9520	2742	2062	2138	20
18	Pomfrets	163	128	181	116	380
19	Black pomfret (Formio niger)	177	138	144	169	457
20	Mackerals(Rastraligs karagurta)	22253	17621	3826	11077	8643
21	Seerfishes	642	1420	1579	1227	737
22	Tunnies	452	498	903	711	148
23	BregmacerosMacelendi	0	136	871	70	436
24	Soles(flat fishs)	2371	4480	2979	3754	3322
25	Sphyraene sp (Baracudas)	1249	85	347	86	114
26	Leiognathus sp	571	170	81	280	729
27	Upeneus sp.	2350	1607	1663	3262	3075
28	Penaeid Prawns	4017	4397	5679	6770	9713
29	Non-penaeid Prawns	321	153	10	294	27
30	Natantion Decapods (Lobsters)	49	16	219	31	9
31	Laetarius	1003	902	1381	1185	1643
32	Loligo duvaucelli(Cephalopoda)	4187	2560	5095	6795	5964
33	Miscellaneous	7717	9197	12062	14927	19095
	TOTAL	95590	88438	87690	106852	115042

Table 4.6.20: Variety wise marine fish product of Ratnagiri zone

(In Tonne)

Sr. No.	Variety	Financial year (APRIL TO MARCH)				
		2010-11	2011-12	2012-13	2013-14	2014-15
1	2	3	4	5	6	7
1	Elasmobranchs	0	4	5	0	0
2	Eels	0	0	6	16	114
3	catfishes	197	170	172	232	99
4	Chirocentrus sp.	13	9	72	14	12
5	Sardine	888	814	686	863	919
6	Hilsa ilisha	1	0	6	34	22
7	Anchovies	0	0	0	0	144
8	Thrissocies	0	51	96	8	262
9	Other Clupieds	60	663	1497	322	177
10	Harpodon nehereus	82	0	0	0	0
11	Perches	0	0	0	0	0
12	Redsnapper	4	0	3	1	15
13	Polynemidae	0	0	0	6	0
14	Sciaenids	34	0	93	35	414
15	Otolithoides sp	658	992	1033	799	1495
16	Trichiuridae (Ribbonfishes)	1196	1439	1093	554	1040
17	Caranx	530	52	316	28	15
18	Pomfrets	10	26	30	3	65
19	Black pomfret (Formio niger)	6	32	48	21	244
20	Mackerals(Rastraligs karagurta)	855	713	403	608	238
21	Seerfishes	72	80	104	85	198
22	Tunnies	17	19	0	75	1
23	BregmacerosMacelendi	0	21	177	70	436
24	Soles(flat fishs)	663	2018	1078	1798	1394
25	Sphyraene sp (Baracudas)	21	56	92	22	96
26	Leiognathus sp	415	155	43	59	611
27	Upeneus sp.	679	244	178	127	357
28	Penaeid Prawns	557	926	1354	967	2614
29	Non-penaeid Prawns	26	0	0	0	0
30	Natantion Decapods (Lobsters)	6	0	77	27	2
31	Laetarius	307	279	520	216	594
32	Loligo duvaucelli(Cephalopoda)	2114	665	1668	1254	267
33	Miscellaneous	3997	4256	5485	4547	6442
	TOTAL	13408	13684	16335	12782	18286

Table 4.6.21: Variety & quarter-wise marine fish production of Maharashtra state

(In Tonne)

Sr. No.	Variety	Financial year (APRIL TO MARCH) Year				
		Q.I	Q.II	Q.III	Q.IV	TOTAL
1	2	3	4	5	6	7
1	Elasmobranchs	1085	1006	1989	2046	6126
2	Eels	508	108	369	299	1284
3	catfishes	1901	1661	5378	6936	15876
4	Chirocentrus sp.	413	729	1265	529	3036
5	Sardine	23998	1492	26132	15510	67132
6	Hilsa ilisha	344	389	793	236	1762
7	Anchovies	3877	1845	7283	7586	20591
8	Thrissocies	1368	1342	3695	1394	7799
9	Other Clupieds	197	950	201	269	1617
10	Harpodon nehereus	5979	8398	19781	16807	50965
11	Perches	52	52	89	93	286
12	Redsnapper	89	68	115	87	359
13	Polynemidae	184	390	1382	712	2668
14	Sciaenids	918	1306	2230	3243	7697
15	Otolithoides sp	3930	1953	7801	6561	20245
16	Trichiuridae (Ribbonfishes)	5425	3469	6394	4855	20143
17	Caranx	1264	610	566	136	2576
18	Pomfrets	1158	5526	4744	1444	12872
19	Black pomfret (Formio niger)	189	819	724	368	2100
20	Mackerals(Rastraligs karagurta)	1517	2806	7959	2812	15094
21	Seerfishes	1201	2211	3599	3354	10365
22	Tunnies	417	775	1344	1051	3587
23	BregmacerosMacelendi	369	166	234	103	872
24	Soles(flat fishs)	2452	586	2689	3677	9404
25	Sphyraene sp (Baracudas)	315	426	136	171	1048
26	Leiognathus sp	101	123	714	59	997
27	Upeneus sp.	4544	335	2155	6016	13050
28	Penaeid Prawns	12300	6843	14310	14449	47902
29	Non-penaeid Prawns	21655	1277	18475	14104	55493
30	Natantion Decapods (Lobsters)	37	29	249	63	378
31	Laetarius	752	327	1086	1117	3282
32	Loligo duvaucelli(Cephalopoda)	2804	4160	9861	9480	26305
33	Miscellaneous	12156	1587	10539	6393	30675
	TOTAL	113499	53764	164363	131960	463585

Table 4.6.22: Variety & quarter-wise marine fish production of Ratnagiri district 2014-15

(In Tonne)

Sr. No.	Variety	Financial year (APRIL TO MARCH)				
		Q.I	Q.II	Q.III	Q.IV	TOTAL
1	2	3	4	5	6	7
1	Elasmobranchs	3	1	53	44	101
2	Eels	23	27	49	23	122
3	catfishes	36	88	201	264	589
4	Chirocentrus sp.	45	6	38	97	186
5	Sardine	19381	898	17570	10065	47914
6	Hilsa ilisha	19	8	0	3	30
7	Anchovies	89	4	331	209	633
8	Thrissocies	2	80	164	26	272
9	Other Clupieds	155	127	173	190	645
10	Harpodon nehereus	130	0	18	13	161
11	Perches	0	0	0	0	0
12	Redsnapper	0	15	0	0	15
13	Polynemidae	4	0	12	10	26
14	Sciaenids	0	105	276	68	449
15	Otolithoides sp	1201	317	1529	558	3605
16	Trichiuridae (Ribbonfishes)	2117	239	1993	1434	5783
17	Caranx	5	0	14	1	20
18	Pomfrets	58	136	128	58	380
19	Black pomfret (Formio niger)	34	29	282	112	457
20	Mackerals(Rastraligs karagurta)	266	1934	4763	1680	8643
21	Seerfishes	157	35	208	337	737
22	Tunnies	37	14	41	56	148
23	BregmacerosMacelendi	0	147	204	85	436
24	Soles(flat fishs)	1499	253	855	765	3322
25	Sphyraene sp (Baracudas)	15	68	31	0	114
26	Leiognathus sp	27	27	646	29	729
27	Upeneus sp.	967	43	443	1622	3075
28	Penaeid Prawns	3658	1348	2579	2128	9713
29	Non-penaeid Prawns	27	0	0	0	27
30	Natantion Decapods (Lobsters)	7	0	1	1	9
31	Laetarius	418	135	753	337	1643
32	Loligo duvaucelli(Cephalopoda)	725	1000	3311	928	5964
33	Miscellaneous	9493	361	6973	2268	19095
	TOTAL	40548	7445	43638	23411	115042

Table 4.6.23: Variety & quarter-wise marine fish production of Ratnagiri zone 2014-15

(In Tonne)

Sr. No.	Variety	Financial year (APRIL TO MARCH)				
		Q.I	Q.II	Q.III	Q.IV	TOTAL
1	2	3	4	5	6	7
1	Elasmobranchs	0	0	0	0	0
2	Eels	23	27	49	15	114
3	catfishes	18	49	29	3	99
4	Chirocentrus sp.	9	0	0	3	12
5	Sardine	393	0	466	60	919
6	Hilsa ilisha	19	3	0	0	22
7	Anchovies	0	0	144	0	144
8	Thrissocies	0	80	156	26	262
9	Other Clupieds	61	66	36	14	177
10	Harpodon nehereus	0	0	0	0	0
11	Perches	0	0	0	0	0
12	Redsnapper	0	15	0	0	15
13	Polynemidae	0	0	0	0	0
14	Sciaenids	0	105	251	58	414
15	Otolithoides sp	323	160	888	124	1495
16	Trichiuridae (Ribbonfishes)	627	0	377	36	1040
17	Caranx	0	0	14	1	15
18	Pomfrets	12	6	46	1	65
19	Black pomfret (Formio niger)	0	5	192	47	244
20	Mackerals(Rastraligs karagurta)	8	78	144	8	238
21	Seerfishes	1	0	23	174	198
22	Tunnies	0	0	1	0	1
23	BregmacerosMacelendi	0	147	204	85	436
24	Soles(flat fishs)	549	203	573	69	1394
25	Sphyraene sp (Baracudas)	15	64	17	0	96
26	Leiognathus sp	14	0	574	23	611
27	Upeneus sp.	188	43	81	45	357
28	Penaeid Prawns	1115	1053	326	120	2614
29	Non-penaeid Prawns	0	0	0	0	0
30	Natantion Decapods (Lobsters)	1	0	1	0	2
31	Laetarius	93	48	428	25	594
32	Loligo duvaucelli(Cephalopoda)	109	0	124	34	267
33	Miscellaneous	3041	88	3029	284	6442
	TOTAL	6619	2240	8172	1255	18286

Table 4.6.24: District 7 zone wise prominent varieties of marine fish production by bagnet & gillnet in Ratnagiri district 2014-15

(In Tonne)

Sr. No	Fishery/prominent variety	XVII Burondi	XVIII Dabhol	XIX Mirkarwada	XX Ratnagiri	District Total
1	2	3	4	5	6	7
BAGNETS:-						
1	Sardine	0	0	0	0	0
2	Anchovies	0	0	0	0	0
3	Harpadonnehereus	0	0	0	0	0
4	Ribbon fish	0	0	0	0	0
5	Promfrets	0	0	0	0	0
6	Penaeid prawns	0	0	0	0	0
7	Non-penaeids Prawns	0	0	0	0	0
8	Other	0	0	0	13	13
	TOTAL	0	0	0	13	13
GILLNETS:-						
1	Elasmobranchs	12	2	4	0	18
2	Catfishes	16	1	7	24	48
3	Chirocentrus sp.	0	2	0	46	48
4	Hilsa ilisha	5	0	0	22	27
5	Seer fishes	8	105	182	174	469
6	Tuna	0	43	60	0	103
7	Pomfrets	0	11	0	0	11
8	Black pomfret	0	2	2	91	95
9	Others	500	223	218	1359	2300
	TOTAL	541	389	473	1716	3119
RAMPAN :-						
1	Saradine	0	0	0	162	162
2	Otolithes sp.	0	0	0	25	25
3	Ribbon fish	0	0	0	0	0
4	Mackerals	0	0	0	0	0
5	others	0	0	0	43	43
	TOTAL	0	0	0	230	230

Table 4.6.25: District, zone &center wise marine fish production & no. of operating boats in Maharashtra

Sr. No	Name of the Center	Mechanized boats	Non-mechanised boats	Fish production in tonne		
		2014-15		2012-13	2013-14	2014-15
1	2	3	4	5	6	7
Ratnagiri Zone						
1	Nawanagar	15	15	1030	537	863
2	Chinchubunder	3	9	330	188	316
3	kharviwada	0	9	8	9	10
4	Kudli	3	9	22	194	23
5	Jambhari	17	60	234	183	283
6	Jaigarh	80	25	3929	4252	6295
7	SakharJaigarh	0	20	62	24	22
8	Varavada	30	5	314	159	140
9	Kalbadevi	45	0	4275	2415	4097
10	Sakharkasarveli	67	9	3784	2485	4887
11	Jaki-mirya	5	75	616	407	188
12	karla	45	50	92	735	178
13	Bhattye	30	35	241	223	173
14	Phansop	2	25	79	36	37
15	Golap-pawas	45	10	570	270	213
16	Purnagad	213	10	184	139	146
17	Ambere	45	10	326	259	213
18	Tulsunda	4	20	91	43	40
19	Mhamurwadi	4	6	109	30	25
20	Ambolgad	1	12	22	17	18
21	Vapad	0	11	8	19	12
22	someshver	20	15	0	24	106
ZONE TOTAL		491	425	16335	12782	18286
DIST-TOTAL		2300	808	87690	106852	115042

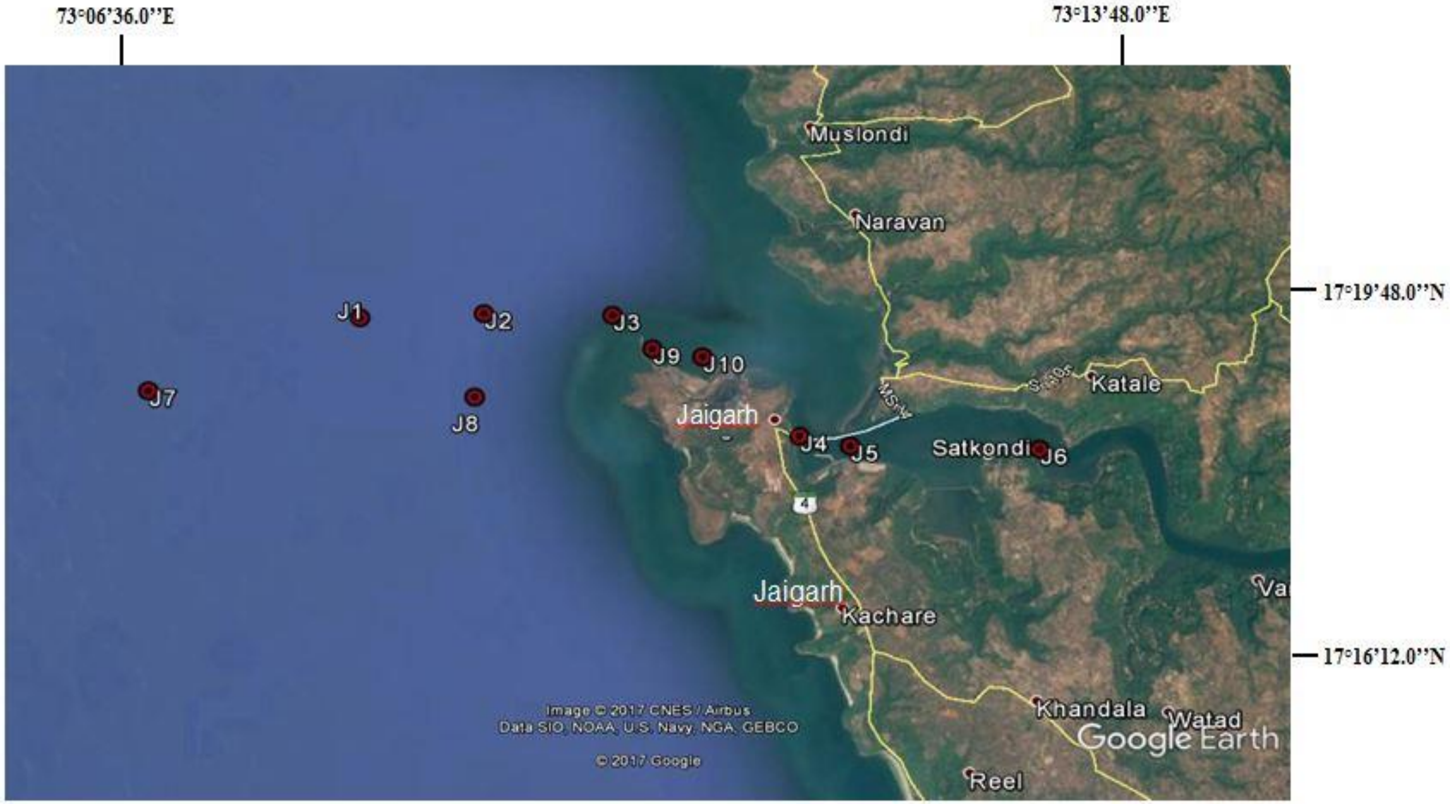


Figure 4.0.1: Sampling Location of Jaigarh

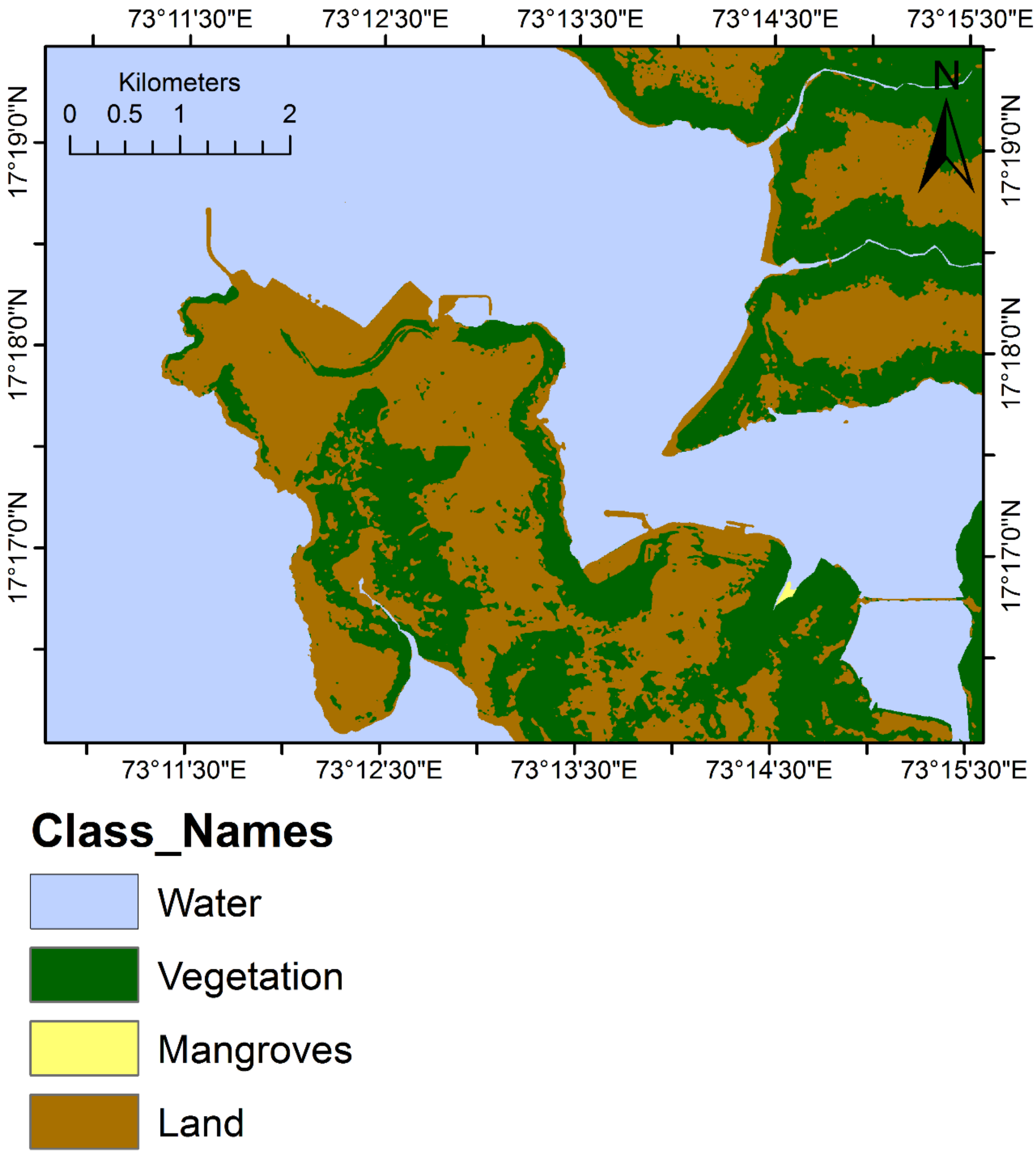


Figure 4.3.1: Land use land cover map by using IRS6 LISS IV of jaigarh

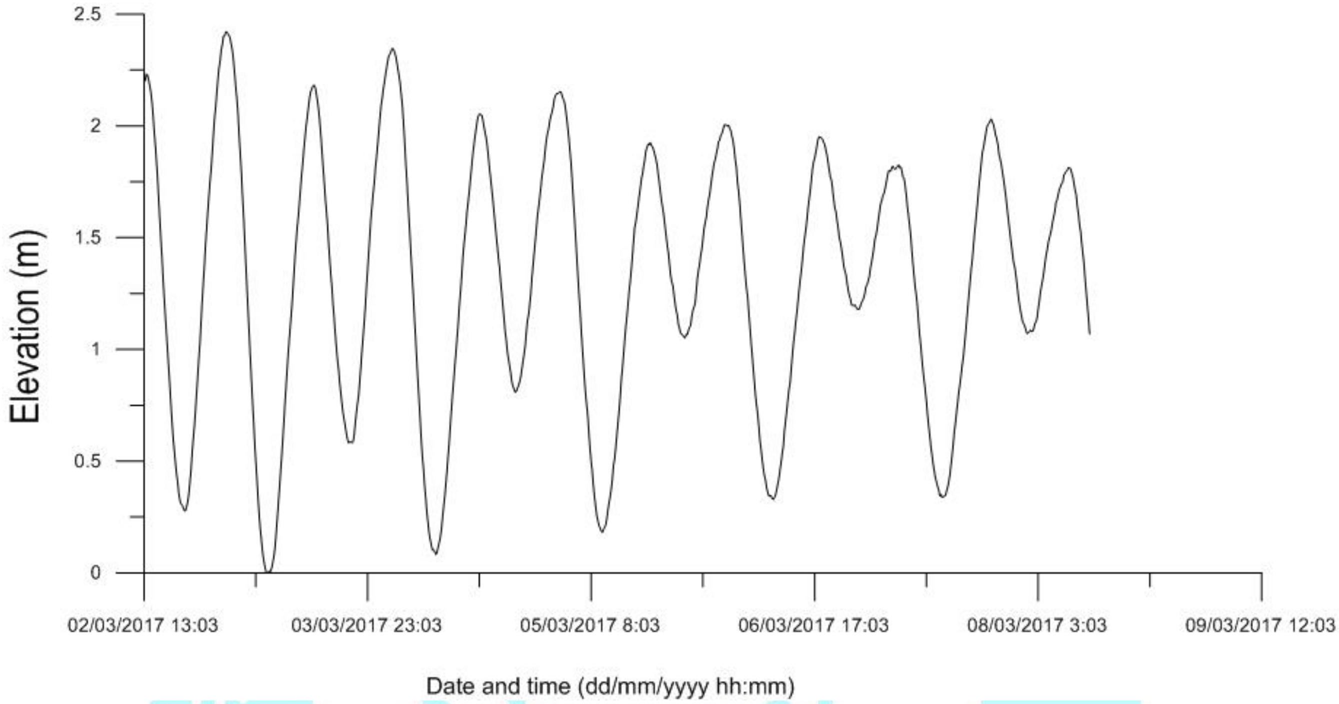


Figure 4.7.1: Tides measured at station J9 from 02/03/2017 to 08/03/2017

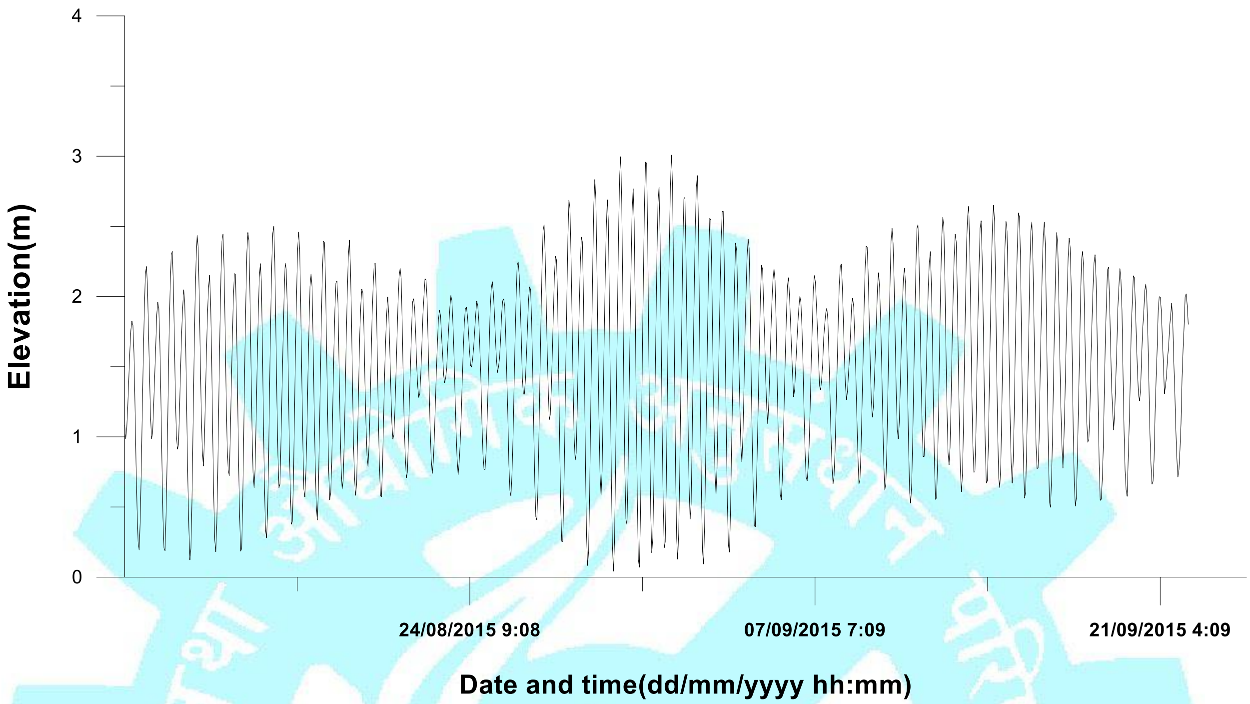


Figure 4.7.2: Tides measured at station J9 from 10/08/2015 to 22/09/2015

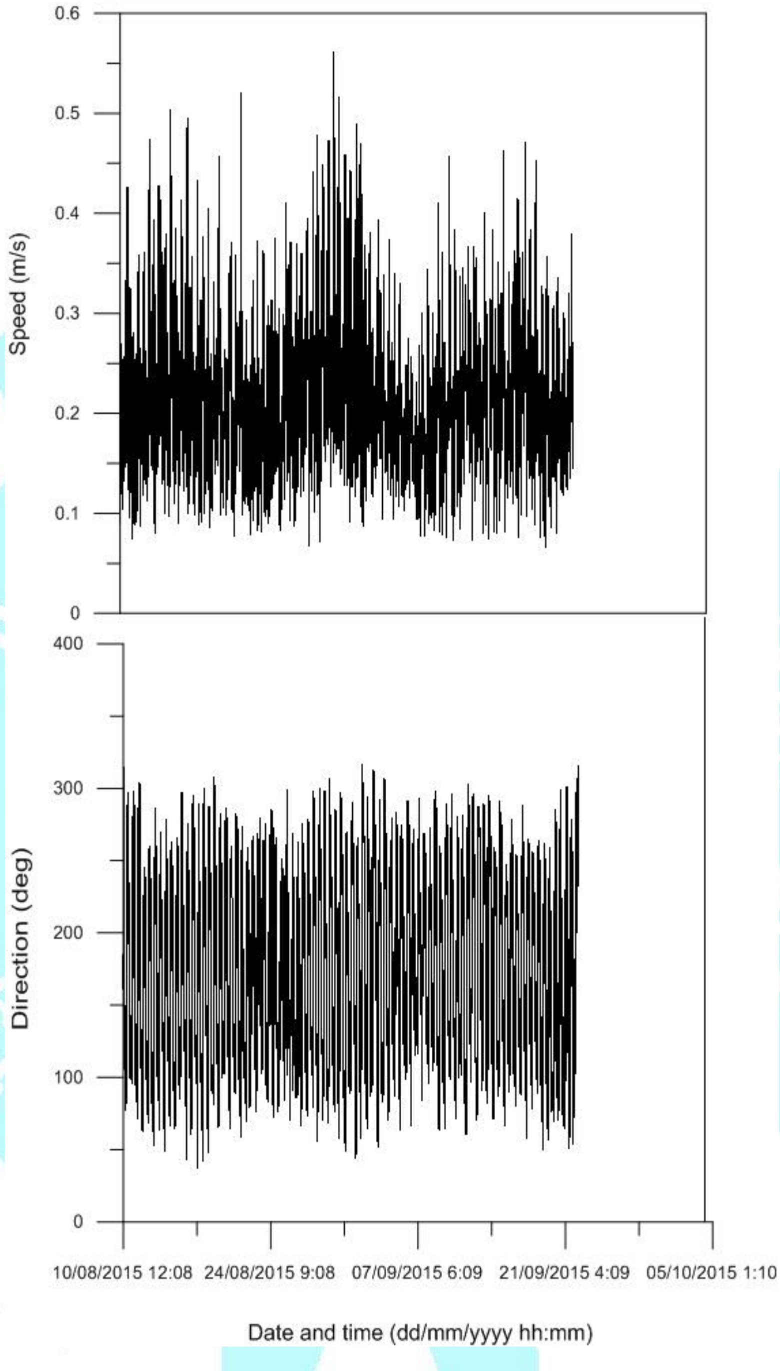


Figure 4.7.3: Currents measured at stationJ9 from surface from 10/08/2015 to 22/09/2015

Figure 4.7.4: Drogue study at station J9 on 03/03/2017 (Eb to Fl)

Figure4.7.5: Drogue study at station J9 on 07/03/2017 (Fl to Eb)

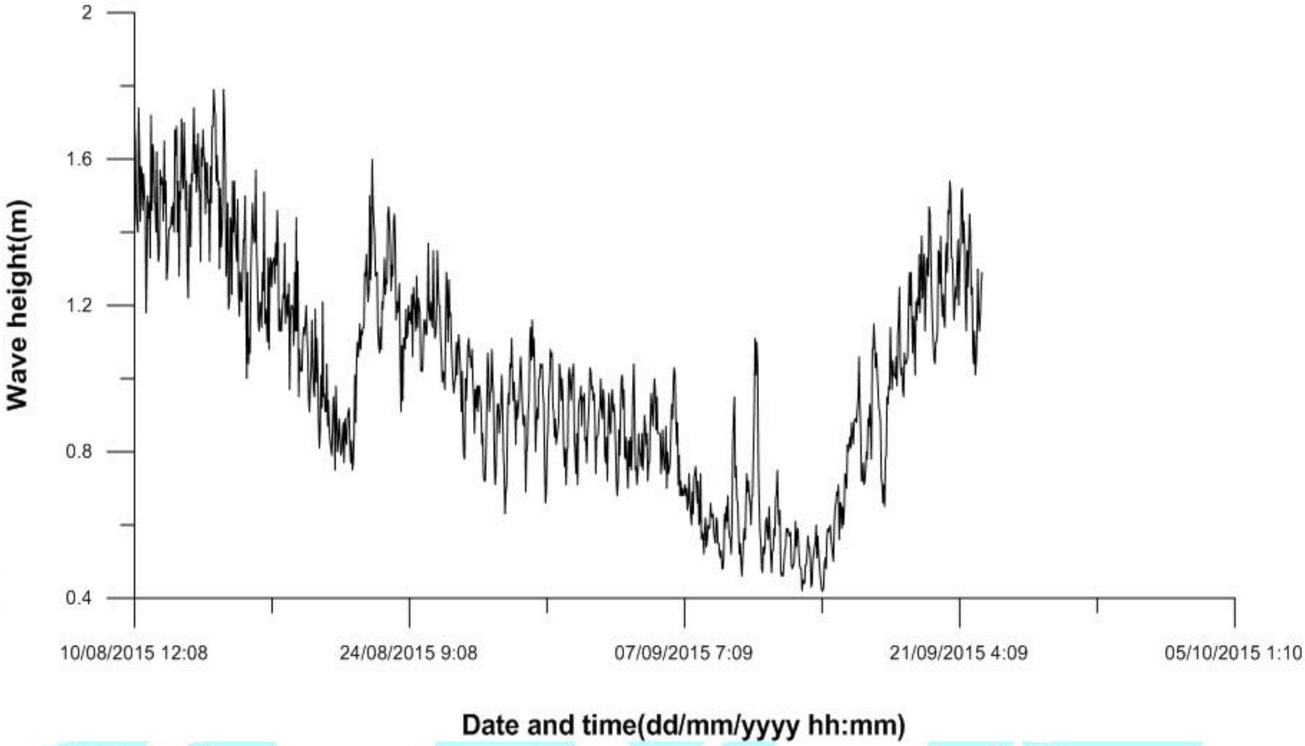


Figure 4.7.6: Waves at station J9 from 10/08/2015 to 22/09/2015

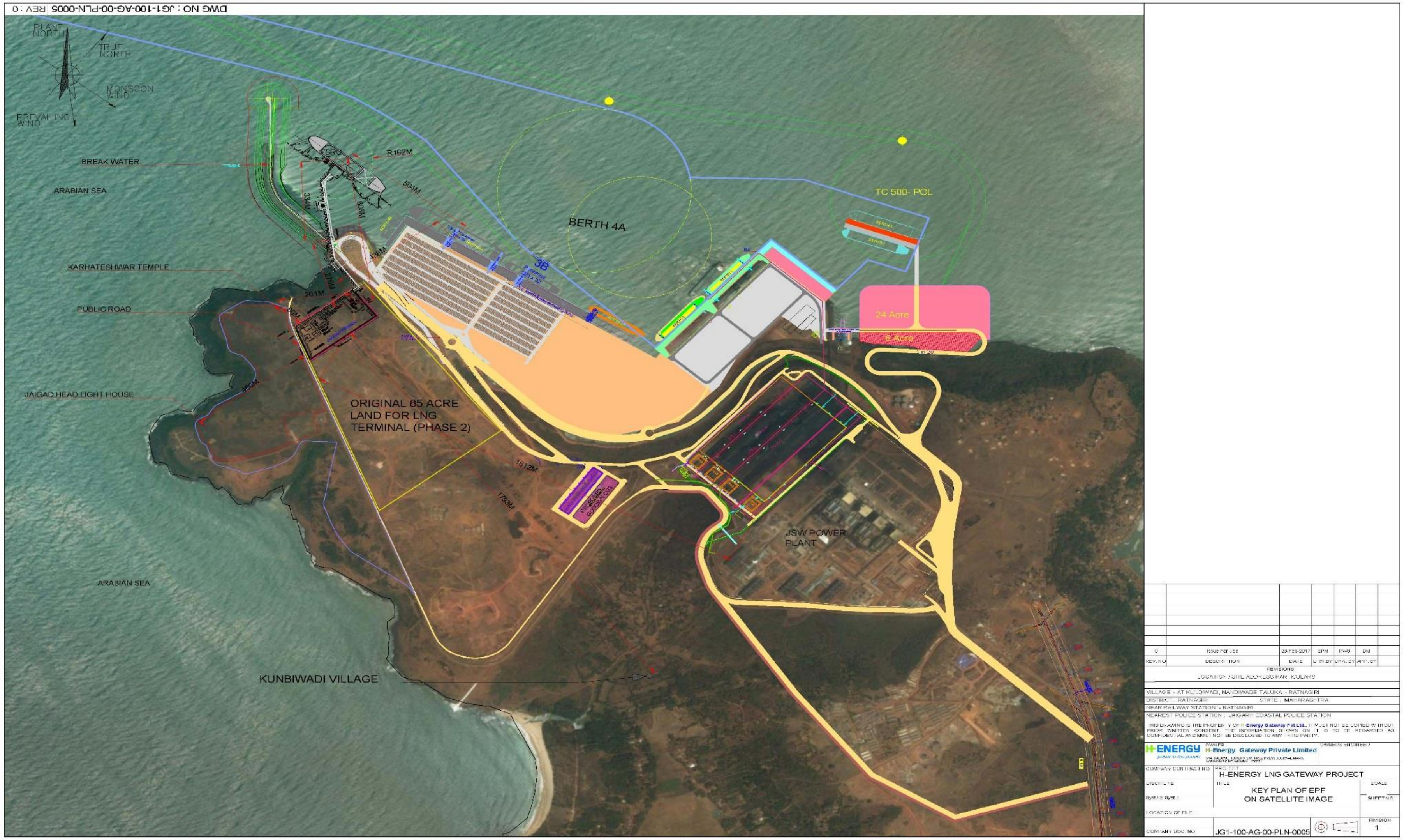
Plate 1 :Photo showing collection of bottom water sample

Plate 2 : Photo showing collection of sediment

Plate 3 : Photo showing retrieving fish net

Plate 4 :Photo showing fish catch after 1 h trawling

Annexure – I Key Plan of EPF on Satellite Image.



Annexure - II The plot area secured for the Phase - 1.