Marine EIA Report for Cooling Water Intake System of the Proposed 1 x 660MWExpansionPower Plant at Ennore Thermal Power Station, Village Ernavur, District Thiruvallur, Tamil Nadu

Proposed by

Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO)

EIA CONSULTANT

NABET Accredited EIA Consulting Organisation
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JULY 2019

DECLARATION BY PROJECT PROPONENT

Tamil Nadu Generation and Distribution Corporation Limited has conducted the "Rapid Marine EIA Report for the Cooling Water Intake System of the Proposed 1x660 MW Expansion Power Plant at Ennore Thermal Power Station, Ernavur Village, Thiruvallur District, Tamil Nadu"

The Rapid Marine EIA report preparation has been undertaken in compliance with the EIA Notification 2006 and CRZ Notification 2011 issued by MoEF&CC. Information and content provided in the report is factually correct for the purpose and objective for such study undertaken.

We hereby declare the ownership of contents (information and data) of Rapid EIA/EMP Report.

For on behalf of Tamil Nadu Generation and Distribution Corporation Limited.

Signature:

Name:

Designation:

DECLARATION BY EIA CONSULTANT

Rapid Marine EIA Report on "Cooling Water Intake System of the Proposed 1x660 MW Expansion Power Plant at Ennore Thermal Power Station, Ernavur Village, Thiruvallur District, Tamil Nadu"

This Rapid Marine EIA report has been prepared by ***Cholamandalam MS Risk Services Limited (CMSRSL)****, in line with "EIA Notification, dated 4th September 2006 and CRZ Notification, dated 6th January 2011, seeking Environmental Clearance and CRZ Clearance from the Ministry of Environment, Forests and Climate Change, New Delhi.*

This work has been undertaken in accordance with ***ISO 9001:2008 Quality Management System*** *with all reasonable skill, care and diligence within the terms of the contract with the client, incorporating our General Terms & Conditions of Business and taking account of the resources devoted to it by agreement with the client.*

We disclaim any responsibility to the client and others in respect of any matters outside the scope of the above.

Further, this report is confidential to the client and the use of this report by unauthorized third parties without written authorization from CMSRSL shall be at their own risk.

For and on behalf of ***Cholamandalam MS Risk Services Limited***

Approved by : ***N V Subba Rao***

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DECLARATION BY EIA CONSULTANT

Declaration by Experts contributing to the Rapid EIA for ***"Cooling Water Intake System of the Proposed 1x660 MW Expansion Power Plant at Ennore Thermal Power Station, Ernavur Village, Thiruvallur District, Tamil Nadu*** *". I, hereby, certify that I was part of the EIA team in the following capacity that developed the above Rapid EIA.*

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S. No	Functional Areas	Name of the Expert/s	Involvement (Period and Task)	Signature
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1 INTRODUCTION

M/s Ennore Thermal Power Station (ETPS) is a coal fired power station located in Ernavur village, Thiruvottiyur Taluk in Tiruvallur district, Tamil Nadu, India. ETPS is one of the major thermal power plants in the state. ETPS is owned and operated by the Tamil Nadu Generation and Distribution Corporation (TANGEDCO), a subsidiary of the Tamil Nadu Electricity Board (TNEB). The existing ETPS was established during 1970 - 1975 in an area of about 237 acres having an installed station capacity of 450 MW (3x110 MW + 2x60 MW).

Figure 1-1 Satellite View of Ennore Thermal Power Station

Source: Google Earth

In order to meet the high power demand in the state, TANGEDCO had proposed a 1x660MW supercritical ETPS expansion project in the vacant land within the existing ETPS complex for which the Environmental Clearance was obtained in the year 2009. However, the expansion of ETPS with the supercritical technology within the stipulated period of the extended Environmental Clearance, i.e., 2.6.2019., could not be completed. However, there has been an overall progress of the project which only accounted to 17% of the project which include civil construction of boiler, chimney, ESP and pump house, water treatment plant etc. Upon the

direction of the MoEF&CC to TANGEDCO to initiate the EC process de-novo as per the provisions of the EIA Notification, the Terms of Reference (ToR) was obtained.

The National Institute of Oceanography has undertaken the multidisciplinary oceanographic investigations to determine the suitable location for cooling water intake & hot water discharge outfall and a Marine Environmental Impact Assessment report was prepared to obtain the clearance from Ministry of Environment, Forests, and Climate Change (MoEF&CC). The details of the earlier EC are given in **Table 1-1**and the same has been attached in **Annexure I**.

Table 1-1 Details of Earlier obtained EC

EC letter number	Date of obtaining	Purpose
J-13011/62/2008-IA.II (T)	3rd June, 2009	Expansion unit of 600MW Subcritical
	24th January 2013	Change in Project configuration from 600MW Subcritical to 660MW Supercritical
	18th September,2014	Extension of Validity of EC
	2nd June, 2019	Expiration of 10 Year Validity of EC

As the existing units have served for over 40 years and are in the last phase of their life span, the existing 450 MW units were decommissioned on 31stMarch, 2017. The proposal for expansion by, adopting supercritical technology of 1X660 unit, would improve the capacity of the power generation by ETPS. The Ennore Thermal Power Station has entrusted Cholamandalam MS Risk Services Limited (CMSRSL), Chennai, (an ISO 9001:2008 certified and QCI-NABET accredited EIA consultant organization) to conduct the Marine Environmental Impact Assessment due to intake of seawater for cooling and discharge of coolant water in to Marine environment.

1.1 Project Objectives and Scope

The proposed expansion proposal with 1x660 MW is proposed at the facility of ETPS, and as the project also involves the intake of seawater from the sea for their internal cooling and process. Further, the water used, after use, will be released back into the sea. As per the recommendations of NIO, Goa, the intake has been proposed 650m away from shore and outfall fixed at 250m from shore in different directions to avoid mixing of return water. Owing to that, it is mandated to undertake a Marine Impact Assessment Study for the proposed expansion for the required

statutory clearance – Environmental Clearance from the Ministry of Environment, Forests and Climate Change MoEF&CC. The study would emphasize on the impact the project would incur upon development and commissioning.

1.2 Need for the Study

The proposed expansion project at ETPS involves a 660 MW supercritical technology operating unit which would be classified as Category A project under 1(d) of the Environmental Impact Assessment Notification 2006 - ≥500 MW (coal/lignite/naphtha & gas based) thermal power plant, which attracts environmental clearance from the MoEF&CC. Also, under section 4 clause (ii) sub-clause (f) of the Coastal Regulation Zone Notification, 2011 states that "*foreshore requiring facilities for transport of raw materials, facilities for intake of cooling water and outfall for discharge of treated wastewater or cooling water from thermal power plants*" requires clearance from MoEF&CC. In line with the aforesaid, an EIA assessment for both terrestrial and marine environment is mandated. This report has been drafted exclusively for assessing the marine environment and the potential impact the proposed development would incur.

1.3 Wastewater Discharge Standards for Thermal Power Plants

The proposed facility will generate rejects from desalination plant and also thermal water. As per The Environment (Protection) Rules, 1986, thermal power plants should meet the following discharge standards (**Table 1-2**).

Table 1-2 Discharge Standards for Thermal Power Plants

S. No.	Industry	Parameter	Standards
1	Thermal Power Plants		Maximum Limiting concentrations milligrams per litre (except pH)
2	Condenser Cooling Water (Once through cooling systems)	pH Temperature Free available Chlorine	6.5-8.5 Not more than 5°C higher than the intake water temperature 0.5 mg/l
3	Boiler Blow down	Suspended Solids Oil and Grease Copper(Total)	100 mg/l 20 mg/l 1.0 mg/l

S. No.	Industry	Parameter	Standards
4	Cooling Tower Blow down	Free available Chlorine Zinc Chromium (Total) Phosphate Other Corrosion Inhibiting Material	0.5 mg/l 1.0 mg/l 0.2 mg/l 5.0 mg/l Limit to be established by CPCB
5	Ash Pond Effluent	pH Suspended Solids Oil and Grease	6.5-8.5 100 mg/l 20 mg/l
5A	Thermal Power Plant (Water Consumption Limit)*	Water Consumption	New plants to be installed after 1st January, 2017 shall have to meet specific water consumption upto a maximum of 2.5 m^3/MWh and achieve zero water discharge.
6	Air Emissions*	Particulate Matter Emissions -generation capacity 210 MW or more Sulphur Dioxide (SO2) Oxides of Nitrogen (NOx) Mercury (Hg)	30 milligram per normal cubic meter 100 milligram per normal cubic meter 100 milligram per normal cubic meter 0.03 milligram per normal cubic meter
7	Stack Height/Limit in Meters#	Power Generation Capacity : 500 MW and above 200 MW/210MW and above to less than 500 MW Less than 200 MW/210MW	275m 220 m H=14(Q)0.3 where Q is emission rate of SO2 in kg/hr and H is Stack Height in meters

*TPP (units) to be installed after 1st January, 2017 and mentioned in **Annexure-3**.

As per '*The Environment (Protection) Rules, 1986'* S.No 33 of Schedule-I refers stack height /limit in meters for Thermal power plants

1.3.1 Temperature Limit for Discharge of condenser Cooling water from Thermal Power Plant

The Environment (Protection) Rules under the Environment (Protection) Act,1986 also lays down specific standards for quality of water effluents to be discharged into different type of water bodies (sewers, surface water bodies like lakes and rivers, marine discharge). The proposed project will discharge thermal water along with desalination plant rejects water into sea. The Water (Prevention and Control of Pollution) Act, 1974 for discharge of quality of water effluents into marine should meet the following marine discharge standards:

i. New thermal power plants commissioned after June 1, 1999 - New Thermal Power Plants, which will be using water from rivers/ lakes/ reservoirs shall install cooling towers- irrespective of location and capacity. Thermal power plants which will use sea water for cooling purposes, the conditions below will apply.

ii. New Projects in coastal areas using sea water - The thermal power plants using sea water should adopt suitable system to reduce water temperature at the final discharge point so that the resultant rise in the temperature of receiving water does not exceed 5ºC[1] over and above the ambient temperature of the receiving water bodies.

iii. Existing Thermal Power Plant - Rise in temperature of condenser cooling water from inlet to the outlet of condenser shall not be more than 5ºC. This is not applicable to the proposed project.

iv. Guidelines for discharge point –

1. The discharge point shall preferably be located at the bottom of the water body at mid-stream for proper dispersion of thermal discharge,

2. In case of discharge of cooling water into sea, proper marine outfall shall be designed to achieve the prescribed standards,

3. No cooling water discharge shall be permitted in estuaries or near ecologically sensitive areas such as mangroves, coral reefs/spawning and breeding grounds of aquatic flora and fauna.

1.3.2 Water Quality Standards for Coastal Waters Marine Outfalls

[1] *As per the schedule- I of The Environment (Protection) Rules ,1986*

As per S.No:86 of The Environment (Protection) Rules, 1986 on Water Quality Standards for Coastal Waters Marine Outfall states that "*In a coastal segment marine water is subjected to several types of uses. Depending on the types of uses and activities, water quality criteria have been specified to determine its suitability for a particular purpose. Among the various types of uses there is one use that demands highest level of water quality/purity and that is termed a "designated best use" in that stretch of the coastal segment*". Based on this, primary water quality criteria have been specified for following five designated best uses.

Table 1-3 Primary Marine Water Quality Criteria

Class	Designated Best Use
SW-I	Salt Pans, Shell fishing, Mariculture and Ecologically Sensitive Zone
SW-II	Bathing, Contact Water Sports and Commercial fishing
SW-III	Industrial Cooling, Recreation(non-contact) and Aesthetics
SW-IV	Harbour
SW-V	Navigation and Controlled Waste Disposal

For the proposed project, Primary Water Quality Criteria for Class SW-III waters for Industrial Cooling is applicable and the same has been mentioned below in **Table 1-4.**

Table 1-4 Primary Water Quality Criteria for Class SW-III Waters

S. No.	Parameter	Standards	Rationale/Remarks
1	pH range	6.5-8.5	The range is conducive for propagation of aquatic species and restoring natural systems
2	Dissolved Oxygen	3.0 mg/lit or 40 percent saturation value whichever is higher	To protect aquatic lives
3	Colour and Odour	No noticeable colour or offensive odour	None in such concentration that would impair usages specifically assigned to this class
4	Floating matters	No visible, obnoxious floating debris, oil slick, scum	None in such concentration that would impair usages specifically assigned to this class
5	Fecal Coliform	500/100 ml(MPN)	Not exceeding 1000/100 ml in 20 percent of samples in the year and in 3 consecutive samples in monsoon months.
6	Turbidity	30 NTU	Reasonably clear water for

S. No.	Parameter	Standards	Rationale/Remarks
			Recreation Aesthetic appreciation and Industrial Cooling Purposes
7	Dissolved Iron (as Fe)	0.5 mg/l or less	It is desirable to have the collective concentration dissolved Fe and Mn less or equal to 0.5 mg/l to avoid scaling effect
8	Dissolved Manganese (as Mn)	0.5 mg/l or less	Intentionally left blank as per standards

1.4 Marine EIA Methodology

To undertake the marine impact assessment study for the proposed expansion, TANGEDCO contracted CMSRSL. A Rapid Environmental Impact Assessment was proposed for assessing the marine impact. The study undertaken has been detailed in the following sub-sections.

The marine monitoring was conducted for the Ennore Thermal Power Station to assess the physicochemical properties and the biological characteristics of the marine water (Bay of Bengal), including the tidal influenced Korattaliyar River. An area (marine) encompassed within 10 km radius from the proposed project has been considered as the study area. The locations for assessment were identified off based on the proposed location for intake and outfall points provided by TANGEDCO.

1.4.1 Marine Ecology – Survey, Sampling and Analysis for one season

The biological parameters considered for the present study are phytoplankton, zooplankton, macro-benthos and fishery status. The phytoplankton and zooplankton reflect the productivity of a water column at the primary and secondary levels. Benthic organisms being sedentary animals associated with the sediment/rocky beds, provide information on the integrated effects of stress, if any, and hence are good indicators of early warning of potential damage. Sample collections for marine ecological studies were done by mechanized boat. Ten sampling locations were selected off the coast of Ennore.

1.4.2 Sampling Parameter of Water, Sediments & Marine Ecology

Parameters: The sampling was done with a view to study the existing physico-chemical, biological conditions of the site and the area around the site of around 10 km radius.

Table 1-5 Parameters of the Samples collected

S. No	Particulars	Parameters
1	Surface & Bottom Marine water	pH, TSS, DO, BOD (3days @ 27°C), salinity, Nitrite, Nitrate, Phosphate, Silicates, Oil& Grease, Petroleum Hydrocarbon, Phenols
2	Sediment	Texture (sand, silt, clay), Organic carbon, Calcium Carbonate, Organic Nitrogen, Phenols, Petroleum hydrocarbons
3	Heavy Metals	Copper, Zinc, Iron, Lead, Cadmium, Manganese, Nickel, Mercury, Total Chromium, Hexavalent Chromium

The samples were collected around the core area near the intake and outfall i.e. in the 1km to 3km radii point as well as within the 5km radii. The core area samples will give the direct effect on the ecology and those in the 5km radii will give the diminishing effect. The primary requirements for assessing the impacts are general baseline information as a whole and intensive site-specific data for the area were collected by Cholamandalam MS Risk Services Limited.**Table 1-6** shows the sampling equipment used for marine sampling.

Table 1-6Sampling Equipment used in the study

Components	Sampling Equipment	Pictorial Representation
Water	Depth sampler	

Components	Sampling Equipment	Pictorial Representation
Sediment	Van veen grab	
Phytoplankton & Zooplankton	Heron tranter net	
Benthos	Van veen grab	

Phytoplankton- Water samples were collected for Phytoplankton studies using standard water sampling devices. A measured amount of water samples were fixed by adding "Lugol's Iodine" and stored in cool place under dark condition. Samples were allowed to settle and concentrated to approximate volume in laboratory. 1 ml of each of these concentrates was examined using Sedgwick - Rafter and microscope, with standard reference material (Identifying Marine Phytoplankton – By Grethe R. Hasle and Carmelo R. Tomas, 1997).

Zooplankton- The zooplankton samples were collected as horizontal surface tow with a modified Heron-Tranter (HT) net (having 0.25 m^2 mouth area and 300 µm mesh size). All the samples were preserved in 5% neutralized formaldehyde solution. The zooplankton biomass was later estimated by displacement volume method and readings were converted for 100 m^3. Different zooplankton were sorted, identified and enumerated under stereoscopic zoom binocular microscope. The number were calculated for the whole samples and expressed for 100m^3 of water.

Benthic communities- Sediment samples for benthic community study were collected from the intertidal as well near shore sub tidal regions. Sub tidal sediments were collected with a stainless steel van Veen grab covering an area of 0.04 m^2. The materials collected were preserved in 10% seawater formalin containing Rose- Bengal stain. In the laboratory, all the samples were again washed through a 500-µm-mesh sieve in running water to clear adhering sediment. Later all the organisms were sorted counted and identified (Convey et al, 2003) up to group level. Biomass (wet weight) was taken after removing the debris and expressed as g m^{-2}.

1.5 Impacts assessment prediction

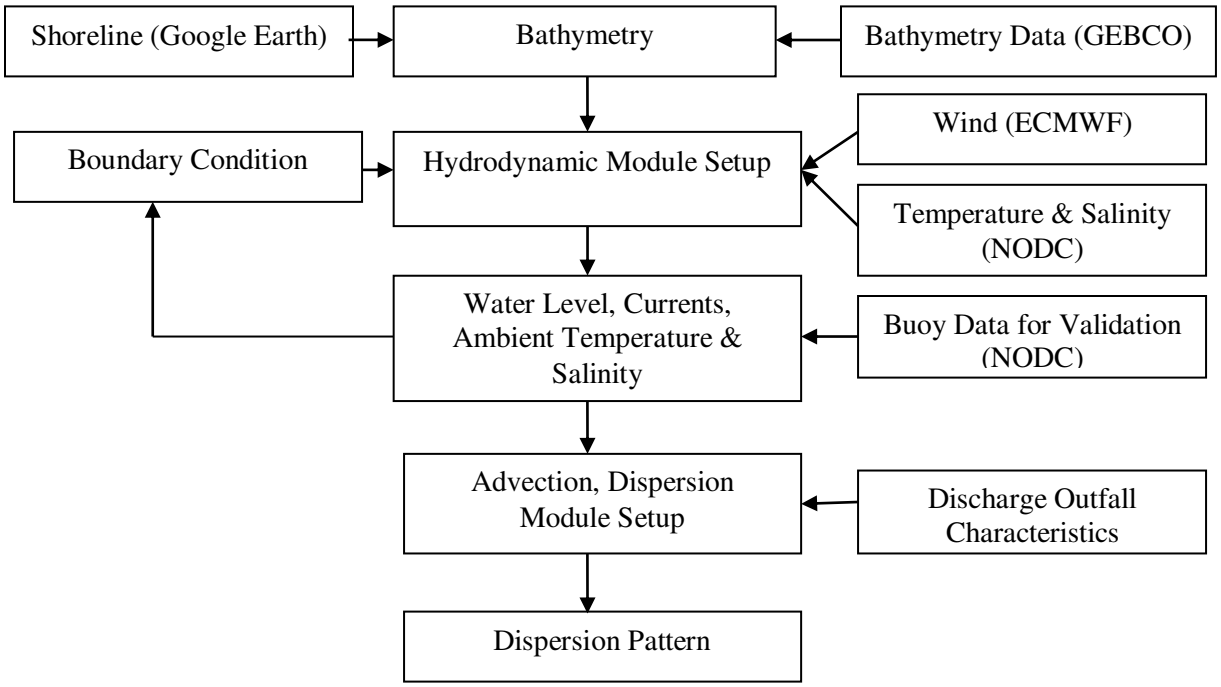
Modelling has been carried out to study the dispersion characteristics of thermal outfall considering the seasonal circulation pattern. The model domain was generated for the study area using General Bathymetry Chart of Ocean (GEBCO) data. To study the circulation features in the study area at base line condition, Hydrodynamic (HD) Module was used. The various parameters considered in Hydrodynamic (HD) module are wind, tide, salinity, and temperature. Wind data was taken from ECMWF (European Center for Medium-Range Weather Forecast). Tide data was simulated using global tidal model. Temperature and Salinity data were taken from the National Oceanographic Data Centre (NODC). The model was calibrated using buoy data from the Indian National Centre for Ocean Information Service (INCOIS).

Thermal and Salinity Dispersion Study has been carried out using Advection-Dispersion (AD) module. The various parameters need to be considered in Advection-Dispersion (AD) module are circulation features from the Hydrodynamic (HD) Module (Water level, Currents) and the characteristics of the discharge outfall (Temperature, Salinity). The methodology has been given in**Figure 1-2.**

Based on the modelling results, the impacts on the environment have been analysed. Temperature and salinity dispersion have been analysed quantitatively and its impacts on aquatic organisms such as phytoplankton, zooplankton and benthic organisms etc, have been qualitatively discussed.

The outcome of the modelling results would determine the impacts on marine ecology due to salinity and temperature. In case of significant impact, a robust Environment Management Plan was suggested to mitigate the impacts on marine ecology during construction and operation phase of the proposed project. To determine the effectiveness of the EMP, appropriate Environmental Monitoring have been suggested during construction and operation phase.

Figure 1-2 Model Methodology



1.6 Structure of EIA Report

The objective of this EIA report is to obtain CRZ clearance for seawater intake for cooling water and discharge of coolant water into Marine environment. Since the objective is to obtain CRZ clearance, the EIA report prepared for the 7 chapters which are detailed below. The chapters

prepared are in line with the EIA Notification 2006 Appendix III of Generic Structure of EIA document only for those sections mentioned in below.

- **Chapter 1** describes the introduction details about the project background, scope of work, methodology adopted for the studies, applicable regulatory context and structure of EIA report proposed.
- **Chapter 2** states the Project Description, details about the seawater intake and outfall of the cooling water from thermal power plants and its associated infrastructure requirements.
- **Chapter 3** presents the Marine Baseline Monitoring Studies of CRZ Area and describes about the marine monitoring sampling of seawater quality, sediment quality, phytoplankton, zooplankton and benthic communities' details.
- **Chapter 4** presents the Marine Impact Assessment and Prediction where the Seawater intake and outfall into marine environment impact will be assessed based on thermal and salinity dispersion modelling studies using 3-dimensional mathematical modelling.
- **Chapter 5** describes the Environment Management Plan of the cooling water intake stem, and the outfall from the thermal power plant
- **Chapter 6** details the Environmental Monitoring Program for the construction and operation phase of the proposed project.
- **Chapter 7** gives the summary and conclusion of the study carried out for the proposed project.

Remaining sections as per the Generic Structure of EIA Document has not been provided because the report is appendix to the EIA report prepared for obtaining EC under EIA Notification for Thermal Power Plant Sector.

2 PROJECT DESCRIPTION

2.1 Introduction

The Tamil Nadu Generation & Distribution Corporation Limited (TANGEDCO) has received Environmental Clearance from MoEF&CC, New Delhi vide letter J 13011/62/2008-IA.II(T) dated 3.6.2009 for ETPS Expansion Thermal Power Plant (1x600 MW) and further obtained amendment for establishing 1x660 MW on 24.1.2013. Subsequently, the extension of validity of EC was obtained for establishing the ETPS expansion with 1x660MW from Ministry of Environment, Forests and Climate Change, Government of India vide letter no: J-13011/62/2008-IA.II (T) dated 18th September, 2014 and the project work is undertaken within the land available in ETPS Complex. However, the construction of the proposed infrastructures could not be completed within the stipulated time as in the EC accorded. Hence, as advised by the MoEF&CC, TANGEDCO has initiated the EC process de novo by obtaining new ToR and conducting the EIA. As the proposed unit will be commissioned within the existing complex, no displacement of people or resettlement and rehabilitation (R&R) are envisaged.

The proposed 1x660MW ETPS expansion works on super critical technology in order to enhance the plant's efficiency and to reduced greenhouse emissions, environmental-friendly/CDM benefits, operation flexibility to grid fluctuations, shorter start-up times, reduced O&M cost and reduced coal consumption.

2.2 Coal Requirement & Transport

100% of the imported coal will be transported through Ennore Port and the annual coal requirement will be about 2 MTPA. For the proposed 660 MW supercritical power plant, it is estimated that 5700 tonnes of imported coal would be required daily. The coal will be transported to the ETPS from the Coal Berth III of Ennore Port through pipe conveyors at the rate of 2x1000 tonnes per hour.

2.3 Water Requirement

As per the MoEF&CC standards and regulations, the thermal power plants using sea water for the process and cooling of facilities has to adopt suitable technology / methods to reduce water

temperature at the final discharge point. The ETPS should ensure that the resultant rise in temperature of the water at the outfall does not exceed 5ºC above the ambient seawater temperature. The seawater requirement for the ETPS for cooling and other purposes is presented inTable 2-1. The total water requirement for the proposed 1x660 MW ETPS expansion project will be about 12,000 m^3/hr, out of which 4,360 m^3/hr will be used for Natural Draft cooling water (CW) makeup for condenser, 5,000 m^3/hr will be used for Auxilliary Cooling Water makeup, 400 m^3/hr will be used as feed to RO plant and 2,000 m^3/hr will be used for Ash and coal handling units and fire protection systems.

Table 2-1Water Requirement

S. No.	Description	Estimated Quantity for the proposed 1x660MW ETPS expansion project	
		m^3/hr	m^3/day
1	CW makeup for condenser	4,360	1,04,640
2	ACW	5,000	1,20,000
3	RO plant	400	9,600
4	Ash Handling system, Coal Handling System & Fire Protection System	2,000	48,000
Total		**11,760**	**2,82,240**

2.4 Flue Gas De-sulfurization (FGD)

To remove the sulphur dioxide from the exhaust flue gas of the thermal power plants the Flue Gas De-sulfurization (FGD) would be used. This measure is also recommended by the International Finance Corporation (IFC) as a good engineering practice for thermal power plants. The same has been considered as part of the ETPS expansion by TANGEDCO. However, TANGEDCO has considered using the Wet FGD using limestone for removal of sulphur dioxide.

2.4.1 Wet FGD

This is also known as “Wet Scrubbing” or the “closed loop system”. In this process, the flue gas is saturated with seawater and the reagents that can be used are limestone ($CaCO_3$), Lime (CaO),

Ammonia (NH_4), and Sodium (Na). The exhaust gases may be neutralized with caustic Soda (NaOH) which is added to freshwater in the closed system.This is a most widely used process since its removal efficiency is upto 98%. Since lime or limestone is not dissolved in water, both are pumped into the scrubber in the slurry form. Though wet scrubbers dominate the market, it has the following disadvantages: high water consumption, wastewater has to be treated and gypsum is the sealable by-product or waste. The wet scrubbers are to be operated with wash water treatment which includes a multicyclone, or a cyclonic separator to remove water-soluble pollutants (SO_2, SO_3, and NO_2). The wet scrubbers also have the advantage of reducing emissions of HCl, HF and gaseous heavy metals.

2.5 Description of Seawater Intake Outfall System

The seawater is proposed to be used for the CW system from the intake well which was earlier proposed by ETPS based on the studies conducted by NIO. The intake water is 25,000m^3/hr, which is adequate to provide water for both the proposed 1x660MW ETPS expansion as well as for 1x660MW ETPS Replacement project, which has been proposed by TANGEDCO. The water requirement for each unit is about 12000m^3/hr. The desalination plant is proposed to provide for sweet water generation which will be used for DM plant and other plant utilities. The physico-chemical characteristics of the sea water are given is**Table 2-2**.

Table 2-2 Intake Seawater Characteristics

Parameter	Units	Value
pH	-	7.6 – 8.0
Temperature	°C	28.3 °C - 28.7
Salinity	ppt	36.6 - 36.9
Total Suspended Solids	mg/l	6 – 10
Dissolved Oxygen	mg/l	6.5 – 6.8
Biological Oxygen Demand	mg/l	2 – 6

The combined intake quantity of both the power plants is 24,000 m^3/hr (2 x 12,000 m^3/hr) and the total discharge quantity will be in the order of 16,000 m^3/hr (2 x 8000 m^3/hr). The intake

system design includes piping from intake point and desilting basin. Two pipelines of OD 1.5m diameter are considered to cater the design requirements of both the plants.

The desalination plant reject (brine) will be let into the sea along with the cooling water return. The total dissolved solids from brine will be diluted when mixed along with the cooling water return. Based on the feasibility assessment done by NIO, the locations for intake of seawater to the plant, and the outlet of the reject and water return has been finalised. The details of the identified location of intake and outfall point are given in **Table 2-3**and illustrated in**Figure 2-1**.

Table 2-3 Details of Intake and Outfall points

Description	Latitude Longitude	Distance from Shore	Depth
Intake point	13°12'7.72"N 80°19'37.96"E	650 m	(-) 8.2 m
Outfall point	13°11'41.53"N 80°19'19.70"E	250 m	(-) 5.4 m

Figure 2-1 Map showing the Intake and Outfall locations of ETPS

Source: Google Earth

The current study is to assess the dispersion of salinity and temperature of the water at the point of outlet and its effect on the marine life. The marine dispersion modelling was conducted and the same were discussed in Chapter 4 of this report.

2.6 Utilization and Infrastructure

The utilities that are required for sea water intake and outfall consists of only cooling water system and is discussed below.

2.6.1 Cooling water system

Natural draft cooling towers are proposed for the cooling water system. The cooling water inlet maximum temperature is to be at 31°C, and the coolant water outfall temperature at the sea is expected to be not more than 36°C. The condenser is to operate at a pressure of 0.1 atm, and the water requirement for the Natural Draft cooling water makeup for condenser will be 4,360 m^3/hr and the water requirement for the ACW makeup will be in the order of 5,000 m^3/hr.

2.7 Employment Potential and Project Cost

The total personnel required for the proposed 1x660MW ETPS expansion will be around 500, of which, 200 will be unskilled workers. The unskilled workforce is to be locally sourced through EPC Contractor.

The overall project cost has been made in the Detailed Project Report. The following fixed and variable costs are considered along with appropriate escalations. The fixed costs include; interest on loan, O&M expenses, interest on working capital, income tax, and depreciation. The variable cost covers the fuel cost (both primary and secondary).

3 MARINE BASELINE ENVIRONMENT CONDITION OF THE STUDY AREA

3.1 Introduction

Marine ecosystems are a complex of habitats defined by the wide range of physical, chemical, and geological variations that are found in the sea. Habitats range from highly productive nearshore regions to the deep sea floor inhabited only by highly specialized organisms. Marine ecosystems are important to humankind both ecologically and economically, providing numerous vital goods and services, and supporting the processes that sustain the entire biosphere.

Marine ecosystem services are provided at the global scale (for example. oxygen production, nutrient cycles, carbon capture through photosynthesis and carbon sequestration) and at the regional and local scales (for example stabilizing coastlines, bioremediation of waste and pollutants, and a variety of aesthetic and cultural values) (MARBEF, 2008).

Marine services include several important economic benefits such as food provision and tourism (Kettunen, 2007). Some of the environmental changes taking place at the global levels are likely to have significant and far-reaching consequences for marine biodiversity. Changes in marine biodiversity are extremely complex processes driven by numerous factors, making it difficult to determine precisely which changes are results of direct human influence. It is clear, however, that deteriorating biodiversity impairs a marine ecosystem's capacity to provide food, maintain water quality and recover from perturbations (Worm et al., 2006).

3.2 Physical Processes:

3.2.1 Geomorphology

Ennore is located in the Thiruvallur district of TamilNadu. The coastline near Ennore is eroding. The mineral resource found in this region is silica sand. The groynes and seawalls are found near Ennore. Ennore creek is located in the northern part of ETPS and the river Korattaliyar discharges in to the Bay of Bengal. Lot of fishing villages are found south of Ennore and these are protected by a combination of seawall and groynes. The region has a very vast coastal plain. The coast consists of sandy beaches. The main geological formations along the coast are upper

Gondwana sands and silts, Quartenary sand and clay undulation by Archean crystalline rocks (Chornockite).

3.2.2 Climate:

The Long-term meteorological data from the "Climatological Normals" published by Indian Meteorological Department (IMD) was referred for understanding the historical trend of meteorology in the study area. The nearest IMD observatory for the project site is located at Chennai (Nungambakkam). The consolidated 30 years (1971- 2000) Climatological data for Chennai (Nungambakkam) Observatory is presented below.

3.2.3 Temperature

In the month of January, the minimum temperature is 20.9° C and maximum is 28.8°C. For the month of May, the minimum temperature is 27.9°C and maximum is 36.8°C. Relative humidity is higher during morning than evening due to sea breeze and land breeze effect. The highest humidity of 83% occurs during the month of November at morning. The lowest relative humidity of 62% occurs during the month of June at evening.The Indian Meteorological Department (IMD) data for temperature is given in **Table 3-1**.

Table 3-1 IMD - Recorded Temperature at Chennai (Nungambakkam)

Month	MEAN*				EXTREMES	
	Daily Max °C	Daily Min °C	Highest in the Month °C	Lowest in the Month °C	Highest °C	Lowest °C
January	28.8	20.9	30.7	18.4	33.1	13.9
February	30.5	22.0	33.0	19.3	36.7	15.0
March	32.5	23.8	35.2	21.2	40.6	16.7
April	34.3	26.4	38.0	23.6	42.8	20.0
May	36.8	27.9	41.4	24.4	45.0	21.1
June	36.9	27.5	40.2	23.7	43.3	20.6
July	35	26.3	38.2	22.9	41.1	21.0
August	34.3	25.7	37.0	22.7	40.0	20.6
September	33.9	25.5	36.0	22.8	38.9	20.6
October	31.8	24.5	35.0	22.2	39.4	16.7
November	29.6	23.0	32.3	20.2	35.4	15.0
December	28.5	21.9	30.2	19.1	32.8	13.9

Annual Mean or High/Low	32.8	24.6	41.4 (5)	18.4(1)	45.0(5)	13.9 (1,10)

3.2.4 Rainfall

The total rainfall in this region was 1202.9 mm in 2017 according to Customized RainfallInformation System (CRIS) of Indian Meteorological Department. The rainfall trend in thelast 5 years (2013-2017) according to the CRIS of IMD department is represented in **Figure 3-1.**The consolidated 30 years (1971- 2000) rainfall data for Chennai (Nungambakkam) Observatory is presented in **Table 3-2.**

Figure 3-1 Total Rainfall per year (2013-2017) from IMD data

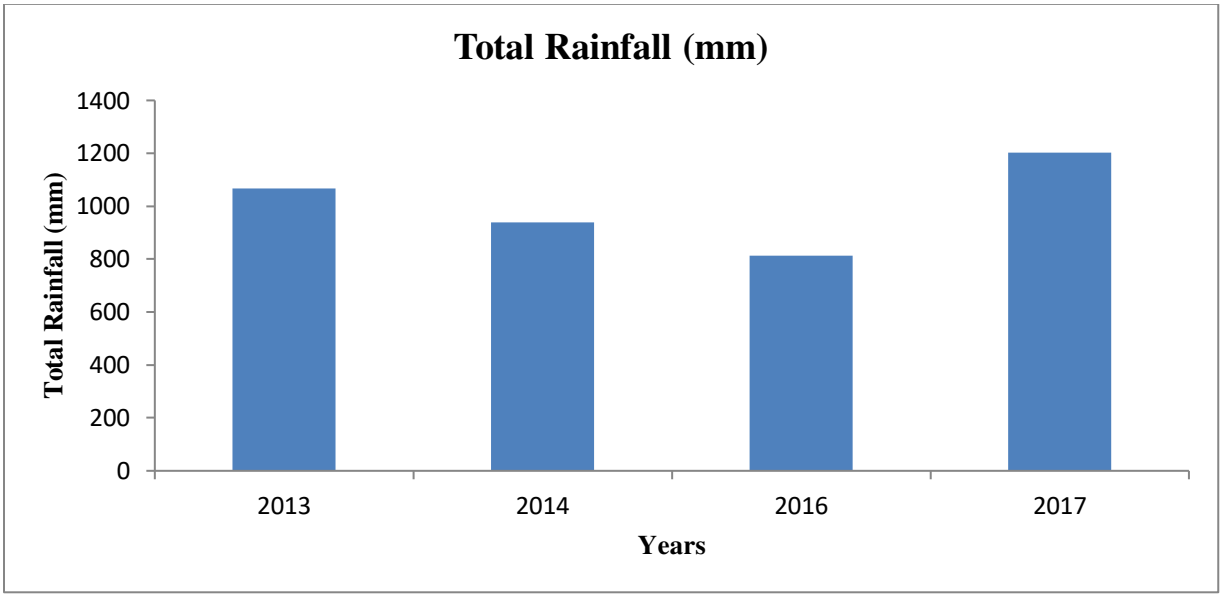


Table 3-2 IMD - Recorded Rainfall at Chennai (Nungambakkam)

Month	Total Rainfall in mm	No. of Rainy days	Heaviest fall in 24 Hours	
			Rainfall in mm	Date and Year
January	22.5	1.3	212.9	15-1915
February	2.2	0.4	294.0	17-1984
March	4.0	0.3	88.1	5-1944
April	7.7	0.6	100.3	12-1951
May	43.9	1.4	244.3	22-1952
June	55.9	4.0	347.9	14-1996
July	100.3	6.9	116.3	28-1910
August	140.4	8.5	94.0	1-1973

Month	Total Rainfall in mm	No. of Rainy days	Heaviest fall in 24 Hours	
			Rainfall in mm	Date and Year
September	137.3	7.1	167.4	12-1996
October	278.8	10.6	279.7	22-1969
November	407.4	11.7	452.4	25-1976
December	191.1	6.3	261.6	10-1901
Annual Mean or High/Low	1391.5	59.1	452.4 (11)	25-1976

3.2.5 Wind Speed

Given below in the **Table 3-3**, is the consolidated 30 years (1971- 2000) Climatological data for wind speed and direction recorded at Chennai (Nungambakkam) Observatory.

Table 3-3 IMD - Recorded IMD wind data at Chennai (Nungambakkam)

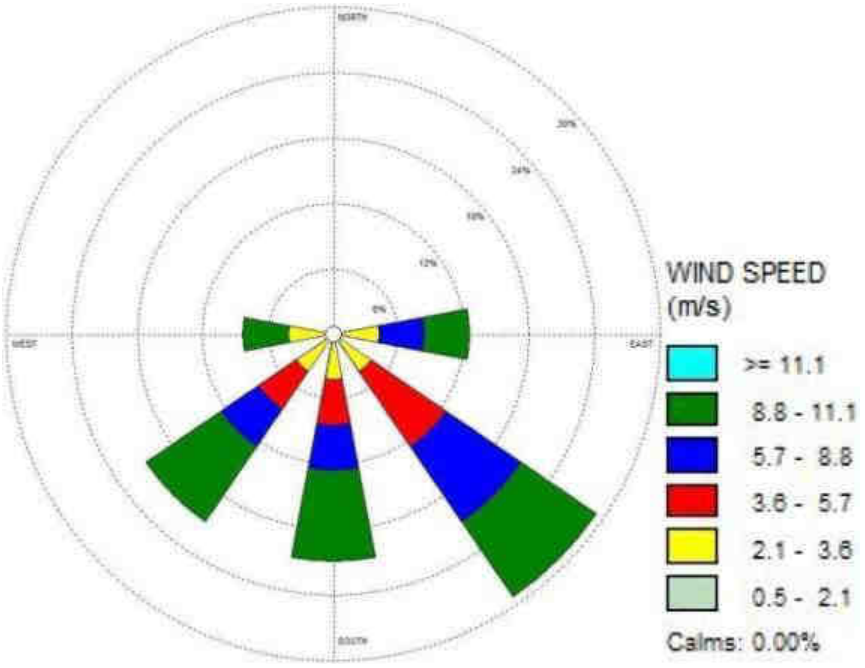
Month	No. of Days with Wind Speed (Km.p.h.)					Percentage No. of Days Wind From							
	62 or more	20-61	1-19	0	N	NE	E	SE	S	SW	W	NW	Calm
January	0	0	18	13	19	14	5	1	0	2	6	9	44
	0	0	28	3	9	44	30	6	1	0	0	0	10
February	0	0	17	11	7	5	6	4	5	10	15	9	39
	0	0	26	2	2	20	37	26	7	1	1	0	6
March	0	0	24	7	3	2	3	5	13	27	18	5	24
	0	0	30	1	1	3	28	46	16	1	1	0	4
April	0	0	26	4	1	0	1	7	30	39	8	1	13
	0	0	29	1	0	1	17	54	24	2	0	0	2
May	0	0	28	3	1	0	1	5	19	38	24	3	9
	0	0	30	1	1	1	12	48	27	5	2	1	3
June	0	1	27	2	0	0	0	1	4	31	54	4	6
	0	0	28	2	0	1	9	30	26	11	14	2	7
July	0	0	27	4	0	0	0	0	3	32	49	2	14
	0	0	27	4	1	1	10	27	22	13	11	2	13
August	0	0	27	4	0	0	0	0	2	30	50	5	13
	0	0	26	5	0	2	7	24	19	16	14	1	17
September	0	0	24	6	1	0	0	2	4	28	39	5	21
	0	0	25	5	1	2	14	30	16	8	8	3	18
October	0	0	19	12	7	6	1	1	3	12	24	7	39
	0	0	24	7	7	21	18	15	8	2	4	2	23
November	0	0	20	10	21	17	5	2	1	3	6	14	31

Month	No. of Days with Wind Speed (Km.p.h.)					Percentage No. of Days Wind From							
	62 or more	20-61	1-19	0	N	NE	E	SE	S	SW	W	NW	Calm
	0	0	26	4	20	41	15	4	2	1	0	3	14
December	0	0	22	9	28	23	6	2	0	1	2	11	27
	0	0	29	2	22	53	12	3	1	0	0	1	8
Annual	0	2	278	85	7	6	2	3	7	21	24	6	24
	0	2	325	38	5	16	17	26	14	5	5	1	11

Windrose Plot

The wind data has been analysed as per the IMD data and the Wind rose plot has been represented in **Figure 3-2.**

Figure 3-2 Windrose plot of the nearest IMD Station – Summer (IMD-Chennai)[2]



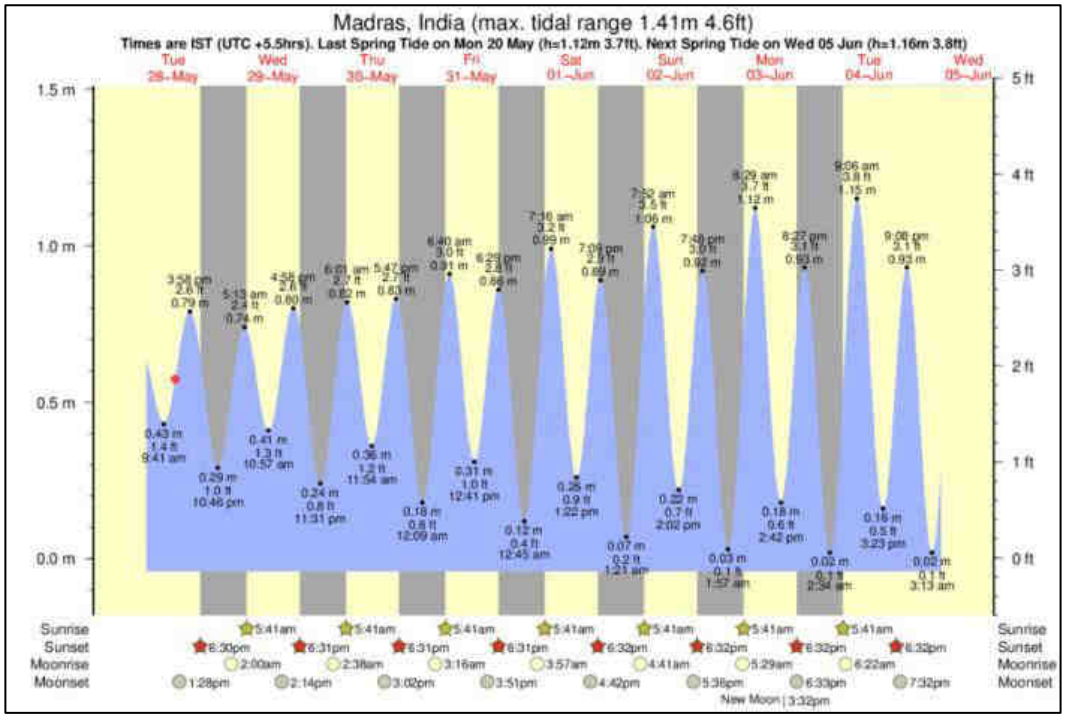
3.2.6 Tides

The maximum tidal range of Chennai coast is 1.41 m. The tides at Ennore are semi-diurnal in nature. The spring tides are the tides with highest water levels and the neap tides indicate the

[2] Climatological Normals (1971-2000) issued by Office of the Additional Director General of Meteorology(Research)- Indian Meteorological Department

lowest water level. The tidal levels for the period of 28th May to 5th June has been obtained and represented in **Figure 3-3**. From the **Figure 3-3**it can be interpreted that the highest water level during spring tides are about 1.12 m on 20th May and 1.16m on 5th June.

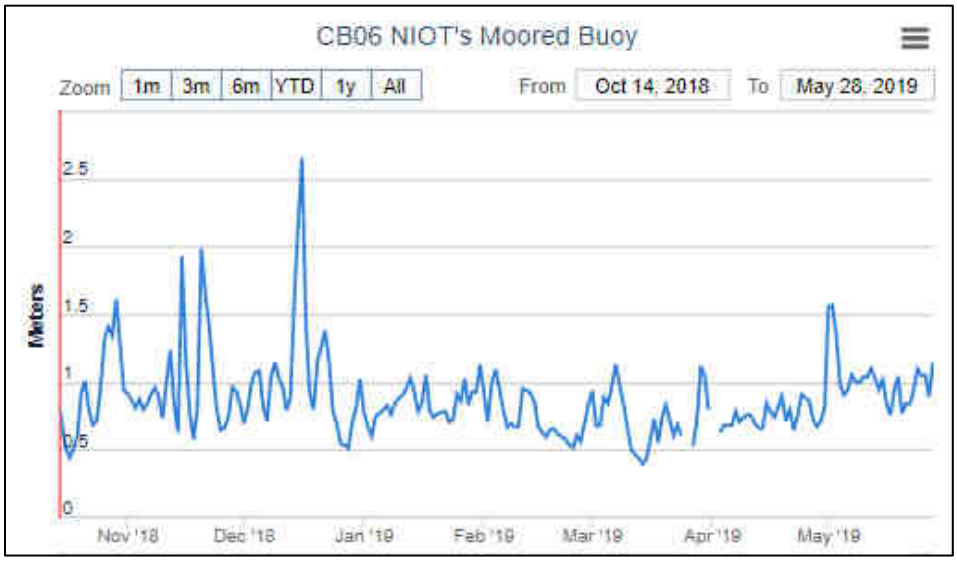
Figure 3-3 Tide Chart of Chennai



3.2.7 Waves

The wave height in the Ennore Coast is maximum to a height of 2.5 m which is as represented below. As shown in the**Figure 3-4** the wave height has been measured by the NIOT moored buoy and the wave height was high during the Northeast Monsoon and the wave height was considerably less during the summer. This is because the wind speeds are high during the Northeast monsoon along the Coromandel Coast.

Figure 3-4 Wave Height in Ennore Coast

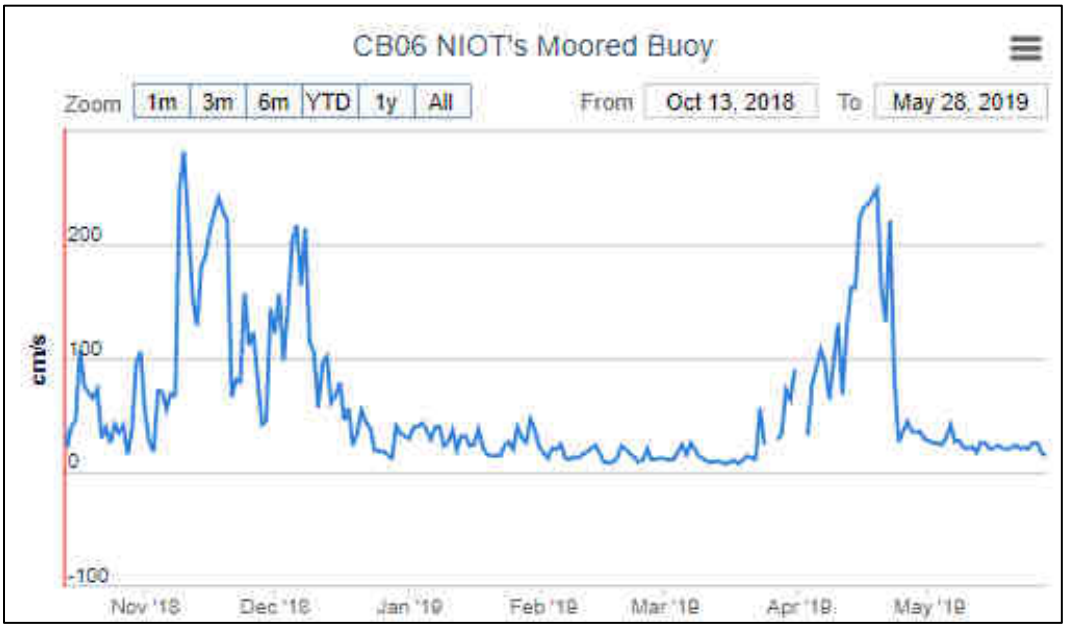


Source: INCOIS- Moored Buoy Data

3.2.8 Currents

The currents in Ennore coast are unidirectional towards south upto February and north for the rest of the time. The current speed as represented in **Figure 3-5** reveals that the current speed during the Northeast monsoon is higher than 200 cm/s (2 m/s) which is directed towards the South and the speed during the other times of the year tend to be below 200 cm/s (2 m/s) which is directed towards North.

Figure 3-5 Current Speed in Ennore Coast



Source: INCOIS- Moored Buoy Data

3.2.9 Bathymetry

The seabed morphology of Ennore coast is complex with varied slopes. The slope is steep (1 in 300) at Ennore creek, while the slope on the northern side is flat (1 in 500) with submerged shoals. These shoals might have been formed due to the interaction of northerly coastal currents and sediment supply through Ennore creek.

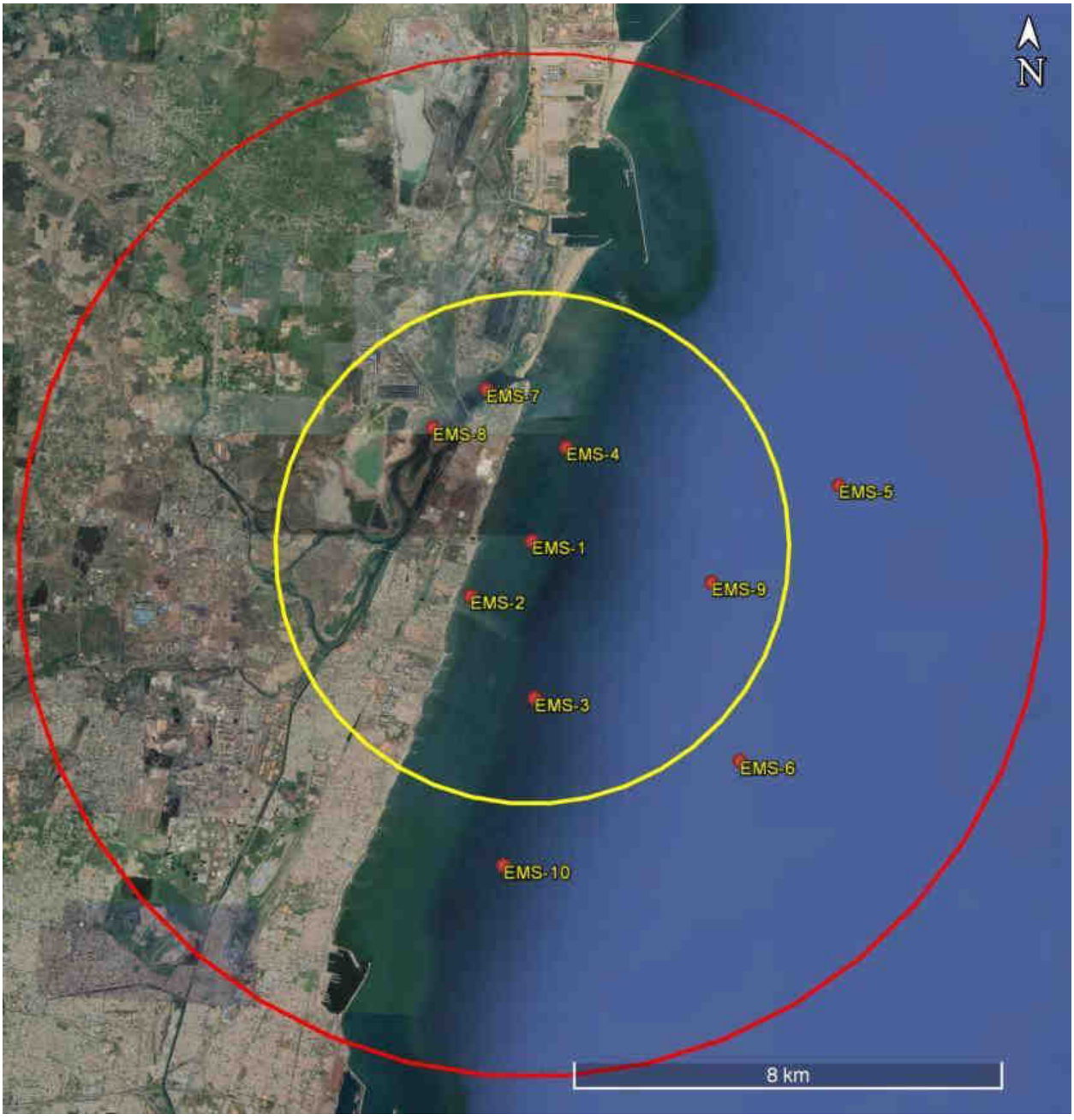
3.3 Sea Water Quality

The sampling was done with a view to study the existing physicochemical, biological conditions of the site and the area around the site of around 10 km radius. **Table 3-4** provides the geo-coordinates of the sampling stations. The samples were collected and were tested in a NABL accredited laboratory. The samples collected from core area will give the direct effect on the ecology and those collected in the 10 km radii will give the diminishing effect. **Figure 3-6** shows the marine baseline sampling locations for 10 km radius. The site sampling photographs are shown in **Figure 3-7.**

Table 3-4 Geo-coordinates of sampling stations off Ennore Coastline

Sr.No	Station	Latitude	Longitude
1	MS-1	13°12'11.93"N	80°19'56.28"E
2	MS-2	13°11'36.86"N	80°19'16.95"E
3	MS-3	13°10'33.16"N	80°19'59.15"E
4	MS-4	13°13'12.17"N	80°20'17.76"E
5	MS-5	13°12'49.05"N	80°23'15.23"E
6	MS-6	13° 9'55.36"N	80°22'9.86"E
7	MS-7	13°13'49.45"N	80°19'25.20"E
8	MS-8	13°13'24.32"N	80°18'50.62"E
9	MS-9	13°11'46.42"N	80°21'52.37"E
10	MS-10	13° 8'50.86"N	80°19'40.69"E

Figure 3-6 Map showing Marine Baseline Sampling Locations (10 km radius)



EMS- ETPS Marine Sampling Locations

Figure 3-7 Marine Sampling Photographs

Marine Sampling (Open Ocean)

Surface Water Collection

Bottom Water Collection

Phyto & Zoo plankton Collection

Benthos Collection

Sediment Collection

Sediment collection

Marine Sampling (Creek Region)

onsite temperature measurement

Bottom Water Collection

3.4 Surface and Bottom Sea Water

The surface seawater quality in the study area was analyzed for 32 parameters including Petroleum Hydrocarbons as per the standard procedures to assess the physico-chemical properties of the water. The temperature of the surface water was recorded between 28.1 °C and

28.6 °C and salinity varied from 36.6 ppt to 37.0 ppt for all the seawater-sampling locations. The conductivity of all the locations was found to be ranging between 56300-56500 µs/cm. The pH ranged between 7.8 and 8.1 indicating that the seawater is slightly alkaline. The values of total suspended solids were found be raging between 2-6 mg/L. The total dissolved solids were found to be between the range of 36615-37000 mg/L for all the sampling locations. The Dissolved Oxygen was found to be between 6.5 mg/L and 6.8 mg/L indicating well mixing of water. BOD values were found to be ranging between 2-6 mg/L indicating that all the locations are free of organic pollution. COD values were found to be ranging between 14-26 mg/L. Nutrients values like nitrite, nitrate were observed to be within the normal range. The value of phosphate was found to be ranging between 210-640 µg/L. All the petroleum hydrocarbons were below detectable limits. Calcium, sodium, potassium and magnesium concentrations were found to be in the range of 470 mg/L – 510 mg/L, 10,350 mg/L- 10,920 mg/L, 420 mg/L- 438 mg/L, 1310 mg/L- 1370 mg/L respectively. Silica was found to be ranging from 0.39-1.10 mg/L. Iron (as Fe) was found to be present in range of 0.10-0.29 mg/L.

The surface water samples were tested for heavy metal concentration and it was observed that at all the locations the concentrations of cadmium, lead, mercury, zinc, arsenic chromium and barium were below the detection limit. Copper and manganese were detected to be in the range of 0.08 mg/L- 0.12 mg/L and 0.05 mg/L- 0.09 mg /L.

Oil and grease were below 2 mg/L for all the samples. The presence of total coliform was observed to be less than 2 MPN/100 ml for sample locations 1, 3, 4, 6, 9 and for sample 2, 5, and 10 it was found to be 11 MPN/100ml. The E.coli count was found to be less than 2 MPN/100ml for all the locations. The total viable count was found to be ranging between 100-300 CFU/ml.

Similarly, the bottom seawater quality in the study area was analyzed for 32 parameters as per the standard procedures to assess the physicochemical properties. The temperature of the seawater was recorded between 27.9-28.7 °C with pH value 7.5- 7.8 indicating that the seawater is slightly alkaline. Total suspended solids were found to be ranging from 4-10 mg/L. The conductivity of all the locations was found to be ranging between 56270-57120 µs/cm. The total dissolved solids were 36582-36986 mg/L for all the marine bottom water sampling locations. The Dissolved Oxygen occurred between 6.3 mg/L and 6.7 mg/L indicating well mixing of

water. BOD values ranged between 3-6 mg/L indicating that all the locations are free of organic pollution. COD values were found to be ranging between 16-28 mg/L. Nutrients values like nitrite, nitrate were observed to be within the normal range. The value of phosphate was found to be ranging between 490-1000 µg/L. All the petroleum hydrocarbons were found to be below detectable limits. Calcium, sodium, potassium and magnesium concentrations were found to be in the range of 430 mg/L – 510 mg/L, 9,990 mg/L- 10,850 mg/L, 420 mg/L- 446 mg/L, 1310 mg/L- 1370 mg/L respectively. Silica was found to be ranging from 0.36-3.60 mg/L. Iron (as Fe) was found to be present in range of 0.26-0.81 mg/L.

The bottom water samples were tested for heavy metal concentration and it was observed that at all the locations the concentrations of cadmium, lead, mercury, zinc, arsenic chromium and barium were below the detection limit. Copper and manganese were found to be in the range of 0.08 mg/L- 0.13 mg/L and 0.05 mg/L- 0.08 mg /L.

Oil and grease were found to be below 2 mg/L for all the samples. The presence of total coliform was observed to be less than 2 MPN/100 ml for all the samples except sample 3, which was found to be 13 MPN/100ml. The E.coli count was found to be less than 2 MPN/100ml for all the locations. The total viable count was found to be ranging between 100-380 CFU/ml. **Table 3-5** shows the details of marine surface and bottom water samples.

Table 3-5 Seawater Quality for Marine Surface and Bottom water samples

S.NO	PARAMETERS	METHOD	UNITS	SW1	BW1	SW2	BW2	SW3	BW3	SW4	BW4	SW5	BW5	SW6	BW6	SW9	BW9	SW10	BW10
1.	Salinity	2520-B-APHA 23rd Edn.2017	ppt	36.6	36.9	36.7	36.6	36.8	36.7	36.7	36.7	37.0	36.7	36.6	36.5	36.9	36.9	36.7	36.6
2.	Conductivity	2510-B-APHA 23rd Edn.2017	µs/cm	56350	56880	56300	56330	56340	56550	56440	56490	56490	56580	56330	56270	56500	57120	56490	56370
3.	Temperature	2550-B-APHA 23rd Edn.2017	°C	28.3	28.7	28.6	28.3	28.2	28.5	28.6	28.1	28.4	28.6	28.2	27.9	28.1	28.6	28.6	28.1
4.	Total Suspended Solids	2540-D-APHA 23rd Edn.2017	mg/l	6	10	2	4	4	8	6	6	4	8	4	6	4	10	6	5
5.	Total Dissolved Solids	2540-C- APHA 23rd Edn.2017	mg/l	36684	36986	36708	36622	36790	36754	36686	36716	37000	36778	36615	36582	36950	36982	36719	36644
6.	pH @ 25°C	4500-H^+-B-APHA 23rd Edn.2017	-	7.9	7.7	8.0	7.6	7.9	7.7	8.1	7.5	7.8	7.8	7.8	7.8	7.8	7.5	8.0	7.7
7.	Dissolved Oxygen	4500-O-C-APHA 23rd Edn.2017	mg/l	6.7	6.5	6.8	6.7	6.5	6.4	6.7	6.6	6.6	6.3	6.7	6.6	6.7	6.7	6.6	6.6
8.	Biochemical Oxygen Demand (BOD) 3 days at 27°C	5210-B-APHA 23rd Edn.2017	mg/l	6	5	2	3	4	4	6	4	4	3	2	3	4	4	3	6
9.	Chemical Oxygen Demand (COD)	5220-B- APHA 23rd Edn.2017	mg/l	24	26	16	16	20	24	26	20	22	18	14	18	20	20	16	28
10.	Oil & Grease	5520-O&G-B APHA 23rd Edn.2017 (Partition Gravimetric Method)	mg/l	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
11.	Nitrite as NO_2	IS 3025 (Part 34)-1988 (R.2014)	mg/l	0.02	0.03	0.03	0.02	0.02	0.02	0.01	0.01	BDL(DL:0.01)	BDL(DL:0.01)	BDL(DL:0.01)	0.02	BDL(DL:0.01)	0.02	0.03	0.04
12.	Nitrate as NO_3	IS 3025 (Part 34)-1988 (R.2014)	µg/l	620	680	410	1200	890	520	970	1100	1100	730	830	1300	900	700	600	1100
13.	Phosphate as PO_4	4500-P-D-APHA 23rd Edn.2017	µg/l	340	900	260	600	440	980	630	790	260	490	210	700	490	1000	640	630
14.	Silica as SiO_2	IS 3025 (Part 35)-1988 (R.2014)	mg/l	0.79	0.36	0.92	0.47	0.71	1.40	1.10	1.30	0.60	3.60	0.42	1.80	0.43	1.40	0.39	2.20

S.NO	PARAMETERS	METHOD	UNITS	SW1	BW1	SW2	BW2	SW3	BW3	SW4	BW4	SW5	BW5	SW6	BW6	SW9	BW9	SW10	BW10
15.	Iron as Fe	IS 3025 (Part 53)-2003 (R.2014)	mg/l	0.26	0.71	0.18	0.36	0.29	0.26	0.22	0.43	0.14	0.80	0.10	0.39	0.23	0.53	0.21	0.81
16.	Sodium as Na	IS 3025 (Part 45)-1993 (R.2014)	mg/l	10800	10840	10900	9990	10920	10570	10610	10700	10500	10640	10350	10380	10500	10850	10740	10650
17.	Potassium as K	IS 3025 (Part 45)-1993 (R.2014)	mg/l	430	442	424	436	426	430	420	420	438	446	420	420	428	436	432	426
18.	Calcium as Ca	IS 3025 (Part 40)-1991 (R.2014)	mg/l	490	430	485	450	478	464	485	472	498	480	470	492	490	510	510	470
19.	Magnesium as Mg	IS 3025 (Part 46)-1994 (R.2014)	mg/l	1334	1344	1310	1310	1316	1360	1370	1370	1340	1360	1320	1340	1320	1340	1360	1350
20.	Copper as Cu	3111-B-APHA 23rd Edn.2017	mg/l	0.10	0.09	0.09	0.11	0.12	0.13	0.11	0.11	0.10	0.10	0.08	0.09	0.10	0.08	0.12	0.11
21.	Manganese as Mn	3111-B-APHA 23rd Edn.2017	mg/l	0.07	0.06	0.06	0.08	0.07	0.07	0.08	0.08	0.06	0.06	0.05	0.07	0.07	0.05	0.09	0.07
22.	Total Coliform	IS 1622:1981 (R.2009)	MPN/100ml	< 2	< 2	11	< 2	< 2	13	< 2	< 2	11	< 2	< 2	< 2	< 2	< 2	11	< 2
23.	*E.coli*	IS 1622:1981 (R.2009)	MPN/100ml	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
24.	Total Viable Count	IS 5402:2012	CFU/ml	300	100	150	200	200	380	100	150	100	100	200	200	100	100	200	100

Note: SW-Surface Water, **BW**- Bottom Water
Locations 1,2,3,4,5,6,9 & 10 are taken in offshore while locations 7 and 8 are taken in creek.

3.5 Marine Sediment

The sediment texture at locations 3, 5, 6 and 9 had maximum percentage of sand and locations 1, 2 ,4, 10 has maximum percentage of clay. The sediments were slightly alkaline in nature with pH values ranging between 7.6 and 7.9. Total Organic carbon ranged from 0.11 to 0.84 %. Calcium carbon was found between 1.92-3.01%. Organic nitrogen ranged between 384-812 mg/kg. Oil and grease were detected to be less than 10 mg/kg for all the samples. Iron levels varied from 0.54-1.22 mg/kg. The details of Marine Sediment Quality are given in**Table 3-6.**

The sediment samples were tested for heavy metal concentration and it was observed that at all the locations the concentrations of cadmium, lead, mercury, arsenic, and barium were below the detection limit. Chromium was found to be BDL for location 3 and 6 and for all other locations it was found to be ranging from 13.36-20.94 mg/kg. Manganese levels were found to be ranging from 44.28-156.45 mg/kg. The concentration of Copper ranged from 3.56-7.62 mg/kg for locations 1, 3, 6, 9, 10 and it was found to be below detection limit for locations 2, 4, 5. Zinc content was found to be ranging from 14.33-33.18 mg/kg. All the Petroleum hydrocarbons tested were found to be below detectable limits for all the samples tested. This indicates that port activities have minimal effect on the sediment quality.

Table 3-6 Marine Sediment Quality Analysis

S.NO	PARAMETERS		UNITS	MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 9	MS 10
1. 1	pH (at 25 °C)		--	7.7	7.6	7.8	7.7	7.9	7.9	7.9	7.8
2. 3	Sediment Texture	Sand	%	21.6	23.2	92.7	23.5	84.2	94.3	88.3	21.7
		Silt		16.7	10.3	5.5	7.7	6.8	4.2	2.1	13.6
		Clay		61.7	66.5	1.8	68.8	9	1.5	9.6	64.7
3. 4	Total Organic Carbon		%	0.71	0.82	0.11	0.75	0.31	0.21	0.38	0.84
4. 5	Calcium Carbonate as $CaCO_3$		%	2.72	3.01	1.92	2.96	2.42	2.1	2.72	2.98
5. 6	Organic Nitrogen		mg/kg	784	812	384	608	544	452	488	677
6. 7	Oil & Grease		mg/kg	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
7. 8	Copper as Cu		mg/kg	3.56	BDL(DL:3.0)	7.62	BDL(DL:3.0)	BDL(DL:3.0)	5.15	3.88	4.12
8. 9	Zinc as Zn		mg/kg	25.64	33.18	20.14	29.9	14.33	18.22	17.77	30.46
9. 10	Iron as Fe		%	0.63	0.54	1.22	0.57	0.61	1.16	0.54	0.59
10. 13	Manganese as Mn		mg/kg	126.32	156.45	44.28	142.44	98.44	48.34	107.38	139.78
11. 15	Total Chromium as Cr		mg/kg	16.44	18.22	BDL(DL:5.0)	20.94	13,36	BDL(DL:5.0)	16.61	17.65

Note: MS- Marine Sediment

3.6 Creek water Quality

3.6.1 Surface and Bottom Creek Water

The surface creek water quality in the study area was analyzed for 32 parameters including Petroleum Hydrocarbons as per the standard procedures to assess the physico-chemical properties of surface sea water quality. The temperature of the surface water was recorded between 28.3 °C and 28.5 °C and salinity varied from 36.4 ppt to 37.1 ppt. The conductivity of all the locations was found to be ranging between 55930-56590 µs/cm. The pH ranged between 7.8 and 7.9 indicating that the seawater is slightly alkaline. The values of total suspended solids were found be raging between 6-9 mg/L. The total dissolved solids were found to be 37066-36355 mg/L. The Dissolved Oxygen was found to be between 6.4 mg/L and 6.5 mg/L indicating well mixing of water. BOD values were found to be ranging between 4-5 mg/L indicating that all the locations are free of organic pollution. COD values ranged between 24-26 mg/L. Nutrients values like nitrite, nitrate were observed to be within the normal range. The value of phosphate was found to be ranging between 340-720 µg/L. All the petroleum hydrocarbons were found to be below detectable limits. Calcium, sodium, potassium and magnesium concentrations were found to be in the range of 465 mg/L – 478 mg/L, 10,650 mg/L- 10,700 mg/L, 430 mg/L- 440 mg/L, 1280 mg/L- 1310 mg/L respectively. Silica was found to be ranging from 1.2-1.3 mg/L. Iron (as Fe) was found to be present in range of 0.42-0.69 mg/L.

The surface water samples were tested for heavy metal concentration and it was observed that at all the locations the concentrations of cadmium, lead, mercury, zinc, arsenic chromium and barium were below the detection limit. Copper and manganese were found to be in the range of 0.10 mg/L- 0.11 mg/L and 0.07 mg/L- 0.08 mg /L.

Oil and grease values were found to be below 2 mg/L for all the samples. The presence of total coliform was observed to be less than 2 MPN/100 ml for both the samples. The E.coli count was found to be less than 2 MPN/100ml for all the locations. The total viable count was found to be ranging between 150-200 CFU/ml.

Similarly, the bottom creek water quality in the study area was analyzed for 32 parameters as per the standard procedures to assess the physico-chemical properties. The temperature of the seawater was recorded between 28.3-28.4 °C with pH value 7.5- 7.6 indicating that the seawater is slightly alkaline. Total suspended solids were found to be ranging from 4-8 mg/L.

The conductivity of all the locations was found to be ranging between 56480-56560 µs/cm. The total dissolved solids were found to be 36708-36768 mg/L. The Dissolved Oxygen was observed between 6.5 mg/L and 6.8 mg/L indicating well mixing of water. BOD values were found to be ranging between 4-5 mg/L indicating that all the locations are free of organic pollution. COD values ranged between 22-26 mg/L for both the creek samples. Nutrients values like nitrites, nitrates were observed to be within the normal range. The value of phosphate was found to be ranging between 1100-1200 µg/L. All the petroleum hydrocarbons were found to be below detectable limits. Calcium, sodium, potassium and magnesium concentrations were found to be in the range of 482 mg/L – 510 mg/L, 10,480 mg/L- 10,520 mg/L, 418 mg/L- 434 mg/L, 1310 mg/L- 1326 mg/L respectively. Silica was found to be ranging from 0.62-3.10 mg/L. Iron (as Fe) occurred between 0.66-0.98 mg/L

The creek bottom water samples were tested for heavy metal concentration and it was observed that at all the locations the concentrations of cadmium, lead, mercury, zinc, arsenic chromium and barium were below the detection limit. Copper and manganese were found to be in the range of 0.1 mg/L- 0.12 mg/L and 0.06 mg/L- 0.09 mg /L.

Oil and grease was found to be below 2 mg/L for all the samples. The presence of total coliform was observed to be less than 2 MPN/100 ml for all the samples. The E. coli count was found to be less than 2 MPN/100ml for all the locations. The total viable count was found to be ranging between 150-200 CFU/ml. **Table 3-7** illustrates the details of the lab test analysis.

Table 3-7 Creek Water Quality for Surface and Bottom water samples

S.NO	PARAMETERS	UNITS	SW7	BW7	SW8	BW8
1.	Salinity	ppt	37.1	36.7	36.4	36.7
2.	Conductivity	µs/cm	56590	56560	55930	56480
3.	Temperature	°C	28.5	28.4	28.3	28.3
4.	Total Suspended Solids	mg/l	6	4	9	8
5.	Total Dissolved Solids	mg/l	37066	36768	36355	36708
6.	pH @ 25°C	-	7.9	7.5	7.8	7.6
7.	Dissolved Oxygen	mg/l	6.4	6.8	6.5	6.5
8.	Biochemical Oxygen Demand (BOD) 3 days at 27°C	mg/l	4	5	5	4
9.	Chemical Oxygen Demand (COD)	mg/l	24	26	26	22
10.	Oil & Grease	mg/l	< 2	< 2	< 2	< 2

S.NO	PARAMETERS	UNITS	SW7	BW7	SW8	BW8
11.	Nitrite as NO_2	mg/l	0.04	0.05	0.07	0.07
12.	Nitrate as NO_3	µg/l	690	1600	510	290
13.	Phosphate as PO_4	µg/l	340	1100	720	1200
14.	Silica as SiO_2	mg/l	1.20	0.62	1.30	3.10
15.	Iron as Fe	mg/l	0.42	0.66	0.69	0.98
16.	Sodium as Na	mg/l	10650	10480	10700	10520
17.	Potassium as K	mg/l	440	434	430	418
18.	Calcium as Ca	mg/l	478	510	465	482
19.	Magnesium as Mg	mg/l	1310	1326	1280	1310
20.	Copper as Cu	mg/l	0.10	0.1	0.11	0.12
21.	Manganese as Mn	mg/l	0.07	0.06	0.08	0.09
22.	Total Coliform	MPN/100ml	< 2	< 2	< 2	< 2
23.	*E. coli*	MPN/100ml	< 2	< 2	< 2	< 2
24.	Total Viable Count	CFU/ml	150	200	200	150

Note: SW-Surface Water, **BW**- Bottom Water

3.7 Creek Sediment Quality

The sediment texture at both the creek locations was found to be maximum clay. The sediments were slightly alkaline in nature with pH values ranging between 7.5 and 7.8. Total Organic carbon was found to be ranging from 0.81 to 0.23 %. Calcium carbon occurred between 4.12-5.42%. Organic nitrogen ranged between 882-1286 mg/kg. Oil and grease were found to be less than 10 mg/kg for all the samples. Iron levels varied from 0.89-1.05 mg/kg.

The sediment samples were tested for heavy metal concentration and it was observed that at all the locations the concentrations of cadmium, lead, mercury, arsenic and barium were below the detection limit. Manganese levels were found to be ranging from 66.72-74.18 mg/kg. The concentration of Copper ranged from 40.64-51.98 mg/kg. Zinc content ranged from 278.32-351.84 mg/kg. The concentration of zinc was found to be high due to sewage contamination from the Chennai Corporation area. Chromium was also present in the creek sediment samples in the concentration 38.28-47.85mg/kg, due to the sewage contamination in the creek. All the Petroleum hydrocarbons tested were found to be below detectable limits for all the samples tested. This indicates that port activities have minimal effect on the sediment quality. The creek sediment analysis results are given in**Table 3-8**.

Table 3-8 Creek Sediment Quality Analysis

S.NO	PARAMETERS		UNITS	MS 7	MS 8
1.	pH (at 25 °C)		--	7.8	7.5
2.	Sediment Texture	Sand		7.2	8.1
		Silt	%	3.1	2.9
		Clay		89.7	89
3.	Total Organic Carbon		%	0.81	2.3
4.	Calcium Carbonate as $CaCO_3$		%	4.12	5.42
5.	Organic Nitrogen		mg/kg	882	1286
6.	Oil & Grease		mg/kg	< 10	< 10
7.	Copper as Cu		mg/kg	40.64	51.98
8.	Zinc as Zn		mg/kg	278.32	351.84
9.	Iron as Fe		%	0.89	1.05
10.	Manganese as Mn		mg/kg	66.72	74.18
11.	Total Chromium as Cr		mg/kg	38.28	47.85

3.8 Marine Ecology

Coastal and marine ecosystems are among the most productive ecosystems in the world, provide many services to human society and are of great economic value (UNEP, 2006). The services include provision of food and water resources, and raw materials like sand, and other high-value heavy minerals like ilmenite, zircon, monazite etc., which are collected from beach sand. They also provide regulating and cultural services, like storm protection, erosion control, tourism and support functions such as climate regulation, oceans and coastal biomes may provide as much as, two-thirds of the ecosystem services that make up the planet's natural capital (TEEB, 2010).[3]

Coastalhabitatsalone account for approximately 30% of all marinebiological productivity. The diversity and productivity are also important for humans. These habitats provide a rich source of food and income. They also support species that serve as animal feed, fertilizers,

[3]*TEEP 2010 The Economics of Ecosystems and Biodiversity: The Ecological and Economic Foundations a TEEP document prepared by Rudolf de Groot Brendan Fisher & Mike Christie, Eds)*

additives in food and cosmetics. Habitats such asmangrovesandsea grassesprotect the coastlines from wave action and erosion. Other areas provide sediment sinks or act as filtering systems.

Marine ecosystems are a complex of habitats defined by the wide range of physical, chemical, and geological variations that are found in the sea. Habitats range from highly productive near shore regions to the deep sea floor inhabited only by highly specialized organisms. Marine ecosystems are important to humankind both ecologically and economically, providing numerous vital goods and services, and supporting the processes that sustain the entire biosphere.

Marine ecosystem services are provided at the global scale (for example. oxygen production, nutrient cycles, carbon capture through photosynthesis and carbon sequestration) and at the regional and local scales (for example stabilizing coastlines, bioremediation of waste and pollutants, and a variety of aesthetic and cultural values).

Marine services include several important economic benefits such as food provision and tourism. Some of the environmental changes taking place at the global levels are likely to have significant and far-reaching consequences for marine biodiversity. Changes in marine biodiversity are extremely complex processes driven by numerous factors, making it difficult to determine precisely which changes are results of direct human influence. It is clear, however, that deteriorating biodiversity impairs a marine ecosystem's capacity to provide food, maintain water quality and recover from perturbations.

Baseline Condition (Secondary Source)

In a study conducted by Hussain, S.M. and Casey, K.E, (2016) on sediment and water samples collected from intertidal zone of north Chennai coast atotal of 34 species of foraminifera belonging to Order Foraminiferida and 14 Ostracoda species to belonging to Order Podocopida were reported. In thisstudy, 34 species of foraminifera, belonging to 15genera, 10 families, 7 super-families and 3 subordersof order Foraminiferida have been reported whereas 14 species ostracod belongingto 12 genera, 6 families, Cytheracea super-family,and Podocopa suborder of the order Podocopidahave been identified.

Foraminifers are almost exclusively marine,unicellular Protists generally consisting of a hardcovering of calcium carbonate called test, haveextensively been used for studies related topaleoclimatic reconstruction, sediment transport etc. Some of the species reported are:*E.incertum E.advenum E.norvangi A.trispinosa L.limbata C.lobatulus N.stella N.sp*

*N.elongatum N. boueanum N.elongatum N. boueanum S costifera S depresa Q polygona Q.lamarckiana Q.kerimbatica Q.costata Q.seminulum Q.sp***.** Ostracods are the tinybivalved Crustaceans found in environment where thecontrolling factors are temperature, bottomtopography, depth, salinity, dissolved oxygen,substrate, food supply and organic matter.Ostracods are considered one of the importantmicrofossil groups in interpreting andreconstructing the paleoclimate and/orpaleoenvironment. Some of the species are: *H. reticulate H. paiki N. iniqua S. kingmai C. keiji L.coralloides C. javana O.morkhovei X. variegate S. kingmai C. keiji* .[4]

In a study conducted by Elumalai et al., (2010) in the area of Ennore creek, Chennai a total of 30 species belonging to 24 genera, 15 families, 2 superfamilies and 2 suborders of Podocopida, have been identified. Of these, four species belong to Platycopa and the rest to Podocopa. Some ostracod species characteristic of brackish water, such as *Cyprideis* cf. *mandviensis*, species of *Hemicytheridea*, *Jankeijcythere mckenziei*, *Kalingella mckenziei*, *Loxoconcha megapora indica* and *Neosinocythere dekrooni* occur in the creek. Freshwater species like *Cyprinotus salinus* were also observedin the outer creek region, i.e. towards riverine side. The occurrence of *Cytherelloidea leroyi*, *Neomonoceratina iniqua*, *Keijella reticulata*, *Neocytheretta murilineata*, *Lankacythere reticulata* and *Mutilus pentoekensis* may be due to the tidal influence. However, *Tanella gracilis* occurs in almost all types of environments ranging from marginal marine to shallow marine environment. Some of the ostracod species like *Basslerites liebaui*, *Jankeijcythere mckenziei*, *Kalingella mckenziei* and *Neomonoceratina jaini* are endemic to Indian waters only. It was concluded that the ostracod assemblage strongly prefers tropical, shallow and brackish water (Oligohaline to Mesohaline) habitat. [5]

Kannan and Thirunavukkarasu, (2017), conducted a study in Ennore mangrove ecosystem and reported that diatoms formed the dominant group followed by blue greens algae and green algae. About 101 species of phytoplankton belonging to diverse groups, such as 48 species belong bacillariophyceae, 34 species to cyanophyceae and 19 species to chlorophyceae were recorded The *Bacillariophyceae*(diatoms) which were found to be

[4]*Hussain, S.M. and Casey, K.E., 2016. Distribution of foraminifera and ostracoda in the north chennai coast (Ennore to Thiruvanmiur), Tamil Nadu: Implications on microenvironment.*

[5]Elumalai, K., Hussain, S.M. and Dhas, C.S.I., 2010. Recent benthic Ostracoda from the sediments of Ennore Creek, Chennai, Tamil Nadu, India. *Journal of the Palaeontological Society of India*, *55*, pp.11-22.

dominant in the area are: *Apanocapsa banarasensis, A. microscopica , Lungbya semiplena, L. putealis, Johannesbaptistia pellucid, Chlorella vulgaris, Chlorella vulgaris, Korshikoviella limnetica, Pleurotanium ehrenbergi, Stephanodiscus niograroe, Lauderia annulata, Leptocylindrus danicus, L. minimus, Gyrosigma bolticum, Pleurosigma elongatum* and *Nitzschia longissima.* Some of the Cyanophyceae (Blue green Algae) reported are*Apanocapsa banarasensis, A. grevillei, A. microscopic, A. pulchra ,Chrooccoccus indicus,C. turgidus, Merismopedia minima, Oscillatioria earli Spirulina laxissima*, *Phormidium retzei*, *Johannesbaptistia pellucid.Some of the Chlorophyceae* (Green Algae) reported are: *Ankistrodesmus falcatus, Closteriopsis longissima, Senedesmus armatus, S.arquatus, S.obilius, Gonatozygon aculeatum, Penium cylindrus, Euastrum spinlosum,S.quaricauda.*[6]

The area comprises of brown or grey coloured mud like sandy sediment. The chanks occur burrowed in the sediment. Bivalves *Tellina coarctata*, *Mactra mera*, live gastropods *Babylonia spirata*, *Murex virqineus*, *Calliostoma tranquebarica, Clanulus microdon, Conus amadis,* egg capsules of sacred chank, egg ribbons of *Tonna dolium* and *Natica tigrina* are abundant. The sea urchins, crinoids, sponges, sea anemone sea fans, stomatopods, the crabs and other size groups Portunuspe/amicus, Charybdis sp, Ocypoda sp and hermit crabs have been recorded. The species of algae like *Gracilaria folifera*. Halimenia sp and Sargassum sp and Lithothamnion and the sea grass Cymodocea were represented in the fishing ground. In addition, empty shells of several bivalves Area complanata, *A. fusca, Cardita bicolar*, *Pecten plica, Pinctada fucata, Tellina* sp Pteria and the gastropods *Oliva gibbosa* and *Turritella acutangula* distributed over the bottom. A variety of fishes like rays, skates, sharks, Lutianus, Lactarius, *Sillago sihama*, Chirocentrus spp, Leiognathus spp, Carangids, Siganus sp, *Saurida tumbil*, *Pseudo rhombus, Lates calcarifer, Pseudosciaena diacanthus, Rachycentron* sp, Cynoglossus, *Pellona Thrissocxles*, *Therapon jarbua*, Nemipterus, *Plotosus*, Platycephalus spp Tetrodon sp, gobids, the prawns *Penaeus semisulcatus*, P. indicus, *Parapenaeopsis uncta* and P. maxillipedo, the lobsters *Panulirus homarus*, P. ornatus, P. versicolor and *Thunus orientialis,* the squid *Loligo duvauceli*, the cuttlefish *Sepia elliptica* and *Sepiella inermis* and octopods etc. have been reported in the trawl net catches.

3.8.1 Methodology

[6]*Kannan, N. and Thirunavukkarasu, N., 2017. Physico-Chemical Parameters and Phytoplankton Diversity of Ennore Mangrove Ecosystem. Res J. Chem. Environ. Sci. 5 (6): 62-72*

The marine monitoring for ETPS TANGEDCO project was conducted on 17th and 18th May 2019 starting 10:00 hrs and completed 16.30 hrs. Samples locations 1 to 6, 9 and 10 falls in offshore and locations 7 and 8 are in Creek area. The proposed sampling locations were identified off shore prior with the help of the co-ordinates. Based on the primary co-ordinates the sampling strategy was planned in such a manner so as to cover the entire area. The biological parameters considered for the present study were phytoplankton, zooplankton, macro-benthos biomass and population and fishery status. The first two reflect the productivity of a water column at the primary and secondary levels. Benthic organisms being sedentary animals associated with the sediment/rocky beds, provide information on the integrated effects of stress, if any, and hence are good indicators of early warning of potential damage. Sample collections for marine ecological studies were done by mechanized boat.

Phytoplankton

Water samples were collected for Phytoplankton studies using standard water sampling depth water sampler. A measured amount of water (2 Litre) samples were fixed by adding "Lugol's Iodine" and stored in cool place under dark condition. Samples were allowed to settle and concentrated to approximate volume in laboratory. 1 ml of each of these concentrates was examined using Sedgwick - Rafter and microscope with standard reference manual.

Zooplankton

The zooplankton samples were collected as horizontal surface tow with a modified Heron-Tranter (HT) net (having 0.25 m^2 mouth area and 300 µm mesh size). All the samples were preserved in 5% neutralized formaldehyde solution. The zooplankton biomass was later estimated by displacement volume method and readings were converted for organisms/m^3. Different zooplankton were sorted, identified and enumerated under stereoscopic zoom binocular microscope. The number were calculated for the whole samples and expressed for organisms/m^3 of water.

Benthos

Sediment samples for benthic community were collected from the intertidal as well near shore sub tidal regions. Sub tidal sediments were collected with a stainless steel Van Veen grab covering an area of 0.04m^2. The materials collected were preserved in 10% seawater formalin containing Rose- Bengal stain. In the laboratory, all the samples were again washed through a 500-µm-mesh sieve in running water to clear adhering sediment. Later all the organisms were sorted counted and identified up to group level.

3.8.2 Observations

Phytoplankton

Phytoplankton recorded from the 10 locations of the project site are represented by 35 species among them 21 species belongs to Bacillariophyceae and 9 species of Dynophyceae 2 species of Chlorophyceae and 3 species belongs to Cyanophyceae. The overall percentage composition of phytoplankton for the 10 locations revealed that the Bacillariophyceae was the dominant group (77%) and followed by Dinophyceae (17%), Cyanophyceae (4%) and Chlorophyceae (2%).

Hierarchy as follows;

Bacillariophyceae > Dinophyceae > Cyanophyceae > Chlorophyceae

Richness and abundance

Phytoplankton community of study area showed wide variation in abundance though species richness remained more or less similar over entire study area. The abundance, occurrence and percentage of phytoplankton species in the study area is given in **Table 3-9**, **Table 3-10** and **Table 3-11** respectively. However, significant temporal variations were observed. Maximum number of species (32 nos.) was observed at stations 1 & 6. Minimum number of species (28nos.) was observed at station 5. Maximum cell count was found at station 3 (11.3 X 10^3/L) minimum cell count was found at Station 6 (7.2 X 10^3/L). Phytoplankton Images recorded during observation are illustrated in **Figure 3-8**, and the dominant species at each of the location are presented in **Figure 3-9**.

Table 3-9 Abundance and species richness of phytoplankton

Station	Cell Count No.sx10^3/L	Total Species	Dominant Genera
1	8.4	**32**	*Coscinodiscus,Ceratium*
2	10.3	**29**	*Coscinodiscus, Chaetocerus*
3	11.3	**30**	*Coscinodiscus, Planktoniella*
4	9.8	**29**	*Coscinodiscus, Ceratium*
5	10.3	**28**	*Coscinodiscus, Ceratium*
6	7.2	**32**	*Coscinodiscus, Ceratium*
7	6.8	**30**	*Coscinodiscus, Chaetocerus*
8	8.5	**29**	*Coscinodiscus, Ceratium*
9	7.7	**29**	*Coscinodiscus, Biddulphia*
10	8.3	**30**	*Coscinodiscus, Ceratium*

Table 3-10 Occurrence of Phytoplankton species in the study area

S. No	Groups	Stations									
		MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10
I	**Chlorophyceae**										
1	*Oocystis minuta*	+	-	+	+	+	+	+	+	+	+
2	*Pediastrum duplex*	+	+	+	+	-	+	+	+	+	+
II	**Cyanophyceae**										
3	*Lyngbya estuarii*	+	-	-	+	+	+	+	+	+	+
4	*Oscillatoria limosa*	+	+	+	+	+	+	+	-	+	+
5	*Phormidium sp.*	+	+	+	+	+	+	+	+	+	+
III	**Bacillariophyceae**										
6	*Amphora brevipes*	+	+	-	+	-	+	+	+	+	+
7	*Amphora bigibba*	-	+	+	-	+	+	+	+	+	+
8	*Bellerochea malleus*	+	+	+	+	+	+	+	-	+	+
9	*Bellerochea mobiliensis*	+	+	+	+	-	+	+	+	-	-
10	*Biddulphia sinensis*	+	-	+	+	+	+	+	+	+	+
11	*Biddulphia mobiliensis*	+	+	+	-	+	+	-	-	+	+
12	*Chaetocerus lorenzienus*	+	+	+	-	+	+	+	+	+	-
13	*Chaetocerus diversus*	+	+	+	+	+	+	+	+	-	+
14	*Coscinodiscus eccentricus*	+	+	+	+	+	+	+	+	+	+
15	*Coscinodiscus marginatus*	+	+	+	+	+	+	+	+	+	+
16	*Coscinodiscus radiatus*	+	+	+	+	+	+	+	+	+	+
17	*Coscinodiscus gigus*	+	+	+	+	+	+	+	+	+	+
18	*Gyrosigma sp.*	+	+	-	+	+	+	+	+	+	-
19	*Planktoniella sol*	+	+	+	+	+	+	+	+	+	+
20	*Pleurosigma sp.*	+	+	+	+	+	+	+	+	+	+
21	*Rhizosolenia sp.*	+	+	+	-	+	+	-	-	+	+
22	*Rhizosolenia alata*	+	+	+	+	+	+	+	+	+	+
23	*Triceratium reticulatum*	+	+	-	+	-	+	+	+	-	-
24	*Amphiprora gigantean*	+	-	+	+	+	-	-	+	+	+
25	*Climacosphenia elongate*	-	-	+	+	+	-	+	+	-	+
26	*Thalassiothrix frauenfeldii*	+	+	+	+	-	+	+	+	+	+
IV	**Dinophyceae**										
27	*Ceratium corridum*	+	+	+	+	+	+	+	+	+	+
28	*Ceratium macroceros*	+	+	+	+	-	+	+	+	+	+
29	*Ceratium trichoceros*	-	+	+	+	+	+	-	+	-	+
30	*Ceratium tripos*	+	+	-	+	+	+	+	+	+	+
31	*Ceratium furca*	+	+	+	+	+	+	-	-	+	+
32	*Peridinium oceanicum*	+	+	+	-	+	+	+	+	+	+

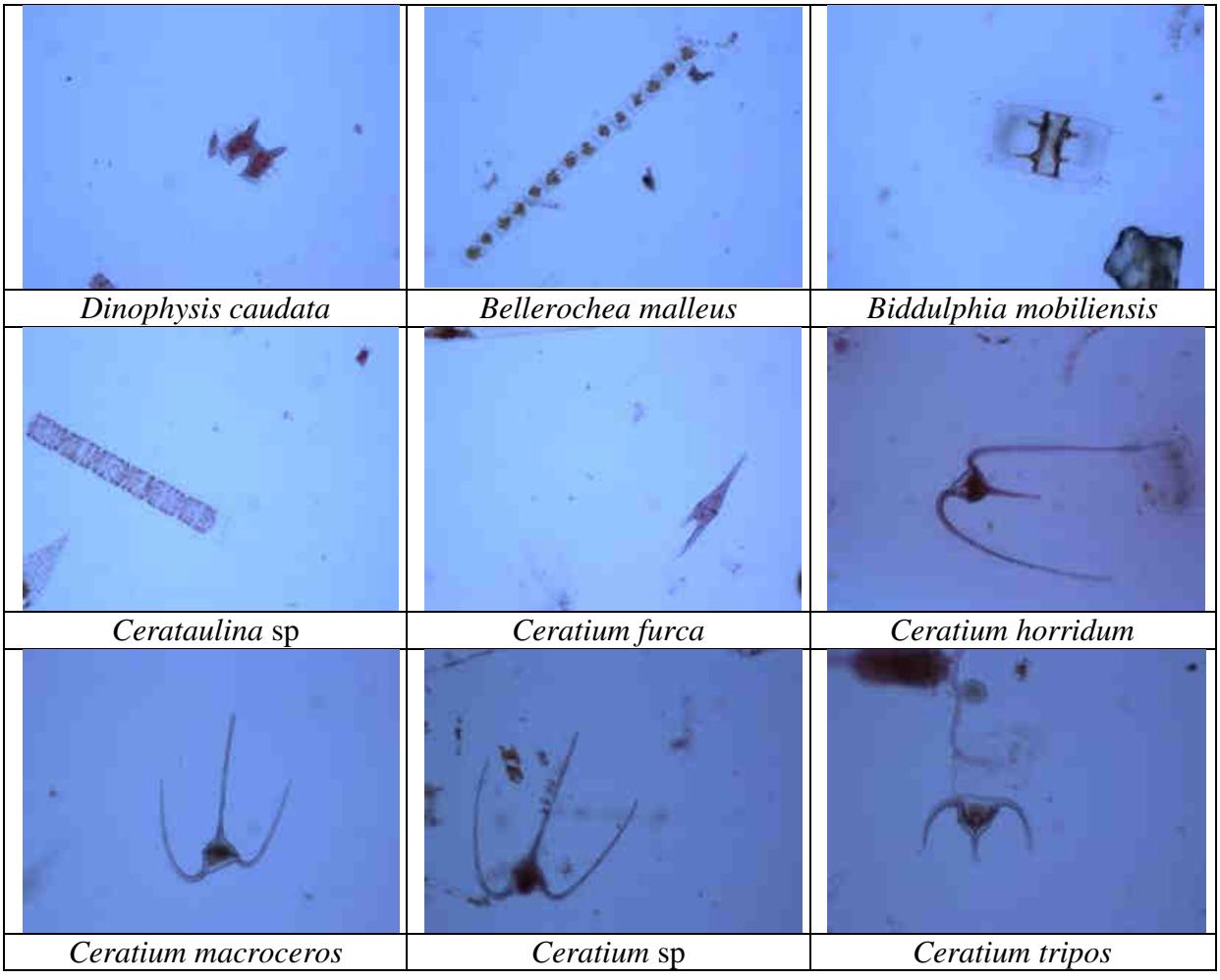
S. No	Groups	Stations									
		MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10
33	*Protoperidinium sp.*	+	+	+	+	+	+	+	-	+	+
34	*Noctiluca miliaris*	+	+	+	+	+	-	+	+	-	+
35	*Dinophysis caudata*	+	-	+	-	-	+	+	+	+	-

Table 3-11 Percentage compositions of Phytoplankton species in the study area

S. No	Groups	Stations									
		MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10
I	**Chlorophyceae**										
1	*Oocystis minuta*	2.1	0	2.23	0.76	1.24	0.52	0.42	0.56	1.3	1.2
2	*Pediastrum duplex*	1.44	1.36	1.43	1.45	0	0.26	1.11	1.84	0.1	0.32
II	**Cyanophyceae**										
3	*Lyngbya estuarii*	1.4	0	0	1.49	0.52	0.56	2.12	0.73	0.64	0.26
4	*Oscillatoria limosa*	3.38	2.73	1.64	1.24	0.83	1.17	2.14	0	2.17	0.46
5	*Phormidium sp.*	1.22	1.43	1.76	1.29	1.03	1	3.54	2.47	1.23	0.48
III	**Bacillariophyceae**										
6	*Amphora brevipes*	1.23	0.57	0	0.85	0	0.65	2.35	2.53	0.65	0.73
7	*Amphora bigibba*	0	2.17	1.64	0	3.4	1.28	3.45	1.44	1.37	5.9
8	*Bellerochea malleus*	2.47	3.65	2.34	2.68	12.4	1.34	6.35	0	1.27	2.53
9	*Bellerochea mobiliensis*	3.67	2.36	1.13	5.37	0	4.71	7.43	2.89	0	0
10	*Biddulphia sinensis*	1.45	0	3.97	1.34	6.43	3.14	5.93	1.78	6.78	2.89
11	*Biddulphia mobiliensis*	3.57	1.53	3.53	0	1.34	2.75	0	0	2.63	1.53
12	*Chaetocerus lorenzienus*	1.59	2.38	2.39	0	6.35	2.87	2.19	1.44	5.26	0
13	*Chaetocerus diversus*	8.15	7.89	4.38	8.72	6.93	7.34	12.65	9.43	0	1.78
14	*Coscinodiscus eccentricus*	10.37	9.63	9.47	7.37	8.65	4.76	6.89	12.94	11.87	9.43
15	*Coscinodiscus marginatus*	6.54	8.36	8.48	11.29	6.47	8.98	2.47	8.27	6.87	8.27
16	*Coscinodiscus radiatus*	12.16	8.34	7.39	8.28	4.78	11.27	4.78	8.14	9.46	8.14
17	*Coscinodiscus gigus*	4.67	6.45	9.35	14.28	0.51	12.98	2.88	4.92	7.87	12.94
18	*Gyrosigma sp.*	1.48	2.43	0	1.46	0.78	3.44	2.46	2.46	1.44	0
19	*Planktoniella sol*	3.29	7.45	8.96	4.48	2.88	2.56	3.98	3.85	5.78	4.92
20	*Pleurosigma sp.*	2.46	3.29	5.24	1.56	0.98	1.33	1.66	1.24	2.49	1.53
21	*Rhizosolenia sp.*	1.35	5.35	2.87	0	3.98	2.37	0	0	3.87	3.85
22	*Rhizosolenia alata*	2.14	1.38	1.81	2.65	2.46	2.49	2.78	5.67	4.43	2.46
23	*Triceratium reticulatum*	1.34	2.17	0	2.36	0	2.67	1.22	1.43	0	0
24	*Amphiprora gigantean*	2.49	0	2.53	2.18	4.67	0	0	3.34	6.67	5.67
25	*Climacosphenia elongate*	0	0	1.54	1.38	2.19	0	1.65	2.89	0	1.44
26	*Thalassiothrix frauenfeldii*	2.19	2.59	2.49	3.87	0	2.35	1.78	2.08	2.45	1.56

S. No	Groups	Stations									
		MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10
IV	**Dinophyceae**										
27	*Ceratium corridum*	**2.15**	**1.57**	**1.34**	**3.15**	**3.5**	**1.45**	**4**	**3.54**	**1.5**	**3.75**
28	*Ceratium macroceros*	**3.24**	**2.6**	**1.56**	**3**	**0**	**2.2**	**2.34**	**4.62**	**1.43**	**4.24**
29	*Ceratium trichoceros*	**0**	**1.54**	**1.22**	**1.8**	**4.41**	**2.89**	**0**	**2.5**	**0**	**0.53**
30	*Ceratium tripos*	**2.19**	**1.68**	**0**	**0.35**	**4.37**	**2.57**	**2.35**	**1.44**	**2.74**	**3.43**
31	*Ceratium furca*	**3.19**	**1.36**	**1.24**	**1**	**3.28**	**2.53**	**0**	**0**	**2.12**	**2.84**
32	*Peridinium oceanicum*	**2.37**	**2.44**	**2.18**	**0**	**1.35**	**1.6**	**2.35**	**1.43**	**1.71**	**2.37**
33	*Protoperidinium sp.*	**1.3**	**1**	**1.45**	**2.89**	**3.02**	**2.53**	**2.14**	**0**	**1.55**	**2.55**
34	*Noctiluca miliaris*	**2.38**	**4.3**	**1.83**	**1.46**	**1.25**	**0**	**2.83**	**2.53**	**0**	**2**
35	*Dinophysis caudata*	**1.03**	**0**	**2.61**	**0**	**0**	**1.44**	**1.76**	**1.6**	**2.35**	**0**

Figure 3-8 Phytoplankton Images recorded during observation



Dinophysis caudata | *Bellerochea malleus* | *Biddulphia mobiliensis*

Cerataulina sp | *Ceratium furca* | *Ceratium horridum*

Ceratium macroceros | *Ceratium* sp | *Ceratium tripos*

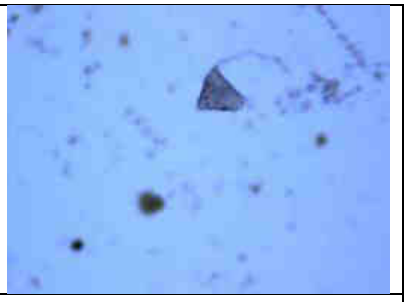
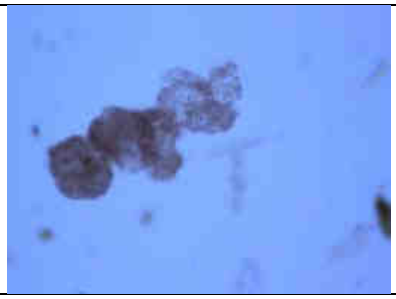
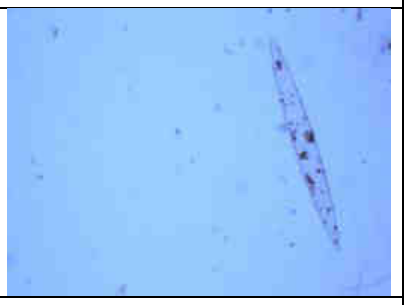
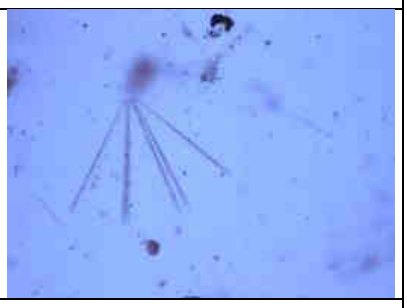
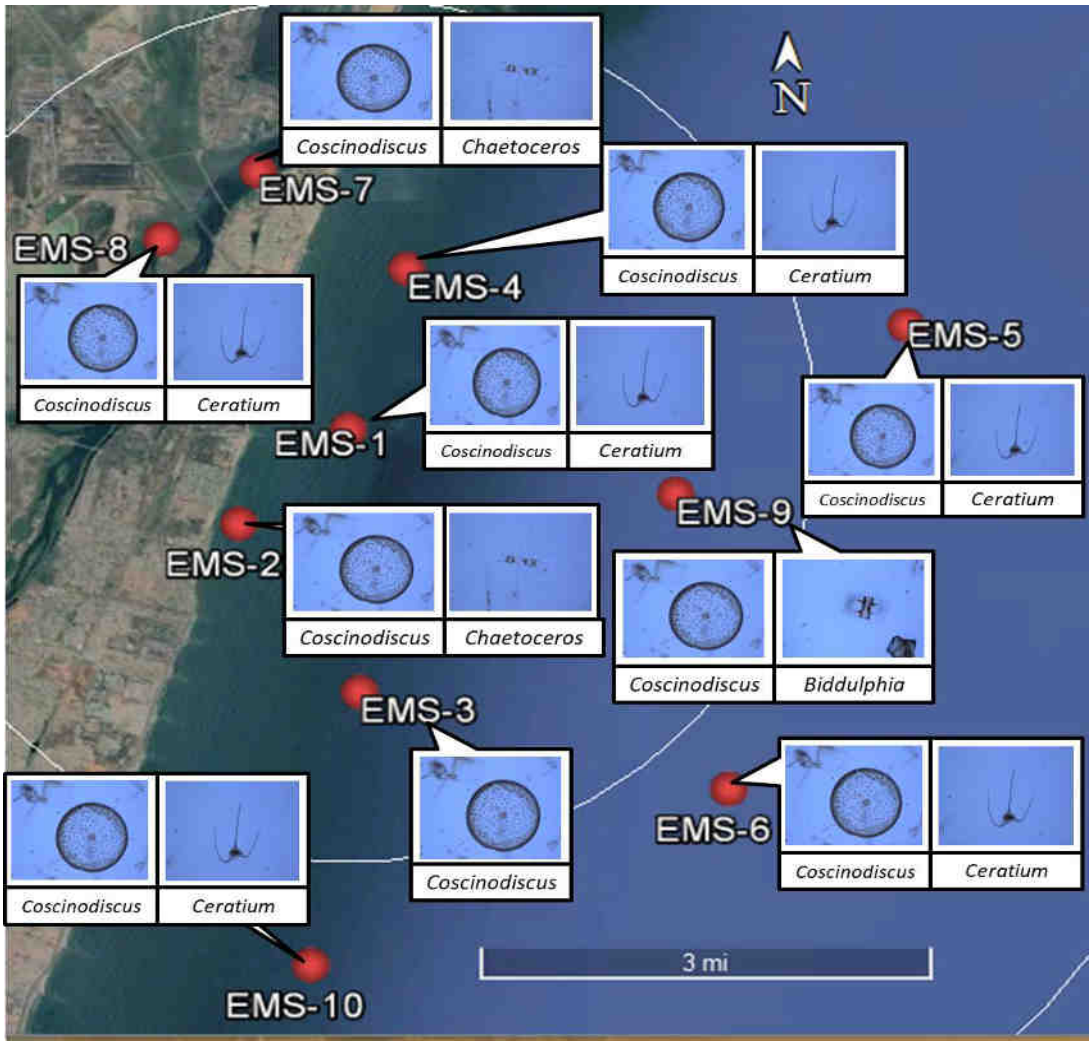
		
Chaetoceros sp	*Coscinodiscus* sp	*Triceratium reticulatum*
		
Gyrosigma sp	*Microcystis* sp.	*Navicula* sp
Pleurosigma sp	*Protoperidinium depressum*	*Rhizosolenia alata*
		
Rhizosolenia crassa	Rhizosolenia sp	*Thalassiothrix fraunfeldii*

Figure 3-9 Phytoplankton recorded during monitoring



3.8.3 Phytopigments

Phytoplankton biomass was estimated in terms of concentration of phytopigments. During May 2019 the levels of chlorophyll ***a***ranged from 1.51-2.73 mg/m^3; with an average of 2.46 mg/m^3 and phaeophytin ranged from 1.11-2.43 mg/m^3 with an average of 1.67 mg/m^3 varied in wide range in the coastal waters of Ennore. This homogenous nature of the water mass perhaps provided stability for the biological processes **(Table 3-12).**

Table 3-12Concentrations of Chlorophyll a and Phaeophytin in Ennore

Station No.	Chlorophyll a (mg/m^3)	Phaeophytin(mg/m^3)
MS 1	3.12	1.95
MS 2	2.97	2.43
MS 3	3.11	1.95

Station No.	Chlorophyll a (mg/m^3)	Phaeophytin(mg/m^3)
MS 4	2.56	2.12
MS 5	1.51	1.12
MS 6	1.76	1.23
MS 7	2.57	1.63
MS 8	2.75	1.57
MS 9	2.33	1.11
MS 10	1.89	1.56
Avg.	**2.46**	**1.67**

Zooplankton

Altogether zooplankton represented by 12 different faunal groups from the study area. Maximum groups were observed at station 5, 8 and 10 (11 groups) while minimum groups were observed in all the other Stations 2 and 6 (9 groups). The occurrence and percentage of zooplankton species in the study area is given in **Table 3-13** and **Table 3-14** respectively.

Composition

During present study zooplankton community in all the stations were mainly dominated by Copepods (average percentage composition 57.48), Polychaeta (avg. % composition 6.34), Amphipoda (avg. % composition 5.33), Crustacean, (avg. % composition 5.12), Tintinnids (avg. % composition 4.81), Bivalves (avg. % composition 4.13), Foraminifera (avg. % composition 3.86), Fish eggs (avg. % composition 3.15), Gastropoda (avg. % composition 2.7), Chaetognatha (avg. % composition 2.55), Fish larvae (avg. % composition 2.55), and Cladocera (avg. % composition 1.98) were commonly found.Zooplankton images recorded during observation are presented in **Figure 3-10**, and their dominance in each of the locations are presented in **Figure 3-11.**

Hierarchy as follows;

Copepoda > Polychaeta > Amphipoda > Crustacea > Tintinnida > Bivalvia > Foraminifera > Fish eggs > Gastropoda > Chaetognatha > Fish Larvae > Cladocera

Abundance and richness

It was evident that there was not much variation in spatial distribution (abundance as well as richness) of zooplanktons over entire study area. Maximum zooplanktons were observed at Station 3 (623X 102/ m3) while that of minimum were observed at Station 6 (302 X 102/ m3) (**Table 3-13**)

Table 3-13 Occurrence of Zooplankton species in the study area

S. No	Groups	Stations									
		MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	M S 7	M S 8	MS 9	MS 10
1	Foraminifer	+	+	+	+	+	+	+	+	+	+
2	Tintinnida	+	+	+	+	+	+	+	+	+	+
3	Copepoda	+	+	+	+	+	+	+	+	+	+
4	Crustacea	+	+	+	-	+	+	+	+	+	+
5	Polychaeta	+	+	-	+	+	+	+	+	+	+
6	Cladocera	-	-	-	+	-	-	+	+	+	+
7	Amphipoda	+	+	+	+	+	+	+	+	+	+
8	Gastropoda	+	+	+	+	+	+	+	+	+	+
9	Bivalvia	+	+	+	-	+	+	+	+	+	+
10	Chaetognath	-	-	+	+	+	+	-	+	+	+
11	Fish eggs	+	+	+	+	+	+	-	+	-	-
12	Fish Larvae	+	-	+	+	+	-	+	-	-	+

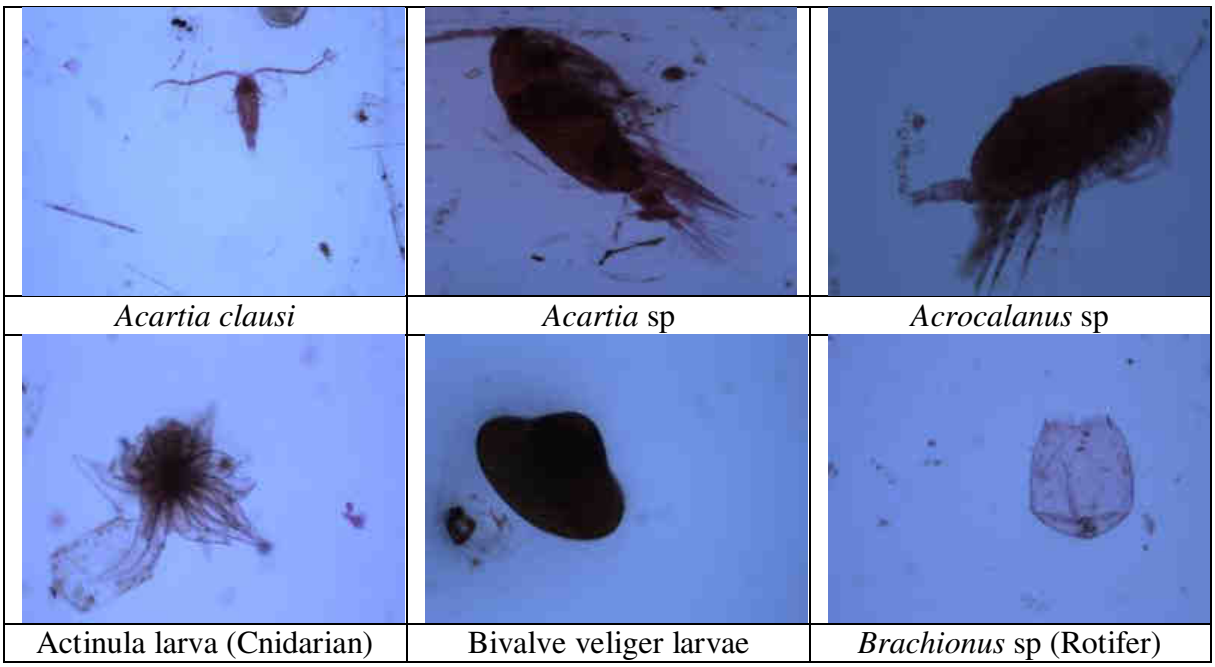
Table 3-14 Percentage compositions of Zooplankton species in the study area

S. No	Groups	Stations									
		MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10
1	Foraminifer a	3.1	3.7	5.2	6	4.4	0	4.6	5.9	3.2	2.6
2	Tintinnida	2.7	8.5	9.3	2.2	2.2	4.8	8.1	4.3	2.3	3.8
3	Copepoda	56.6	49.8	53.9	58.2	48.6	54.3	61. 4	59. 4	63.8	68.8
4	Crustacea	1.3	17.3	2.3	0	7.3	6.8	1.5	3	6.4	5.4
5	Polychaeta	6.1	9	0	1.1	8.4	9.8	7.8	8.2	10.2	2.9
6	Cladocera	0	0	0	3	0	0	5.8	7.4	1.4	2.3
7	Amphipoda	11.2	3.8	5.1	8.5	7.3	5	1.7	4.3	3.9	2.4
8	Gastropoda	2.3	2.3	1.8	3.9	3	3.4	3.2	1.4	2.3	3.3
9	Bivalvia	4.8	1.8	4.1	0	9.8	7.8	3.3	2.2	3.5	4
10	Chaetognath a	0	0	6.1	4.8	3.1	4.9	0	1.3	2.9	2.4
11	Fish eggs	8.8	3.9	4.2	6.4	2.5	3.2	0	2.7	0	0
12	Fish Larvae	3.1	0	8.1	6	3.4	0	2.7	0	0	2.2

Table 3-15Abundance and group richness of Zooplankton

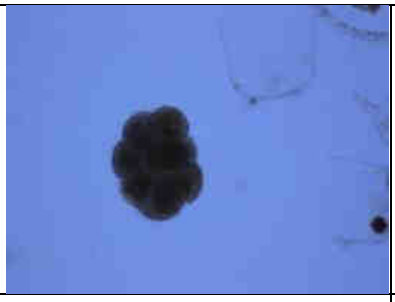
Station	Cell count Nos.x$10^2/m^3$	Total Groups	Dominant Groups
S 1	423	10	Copepod, Amphipoda
S 2	366	9	Copepod, Crustacea
S 3	623	10	Copepod, Tintinnids
S 4	397	10	Copepod, Amphipoda
S 5	364	11	Copepod, Bivalvia
S 6	302	9	Copepod, Polychaetes
S 7	518	10	Copepod, Tintinnids
S 8	378	11	Copepod, Polychaetes
S 9	375	10	Copepod, Polychaetes
S 10	562	11	Copepod, Crustacea

Figure 3-10Zooplankton Images recorded during observation



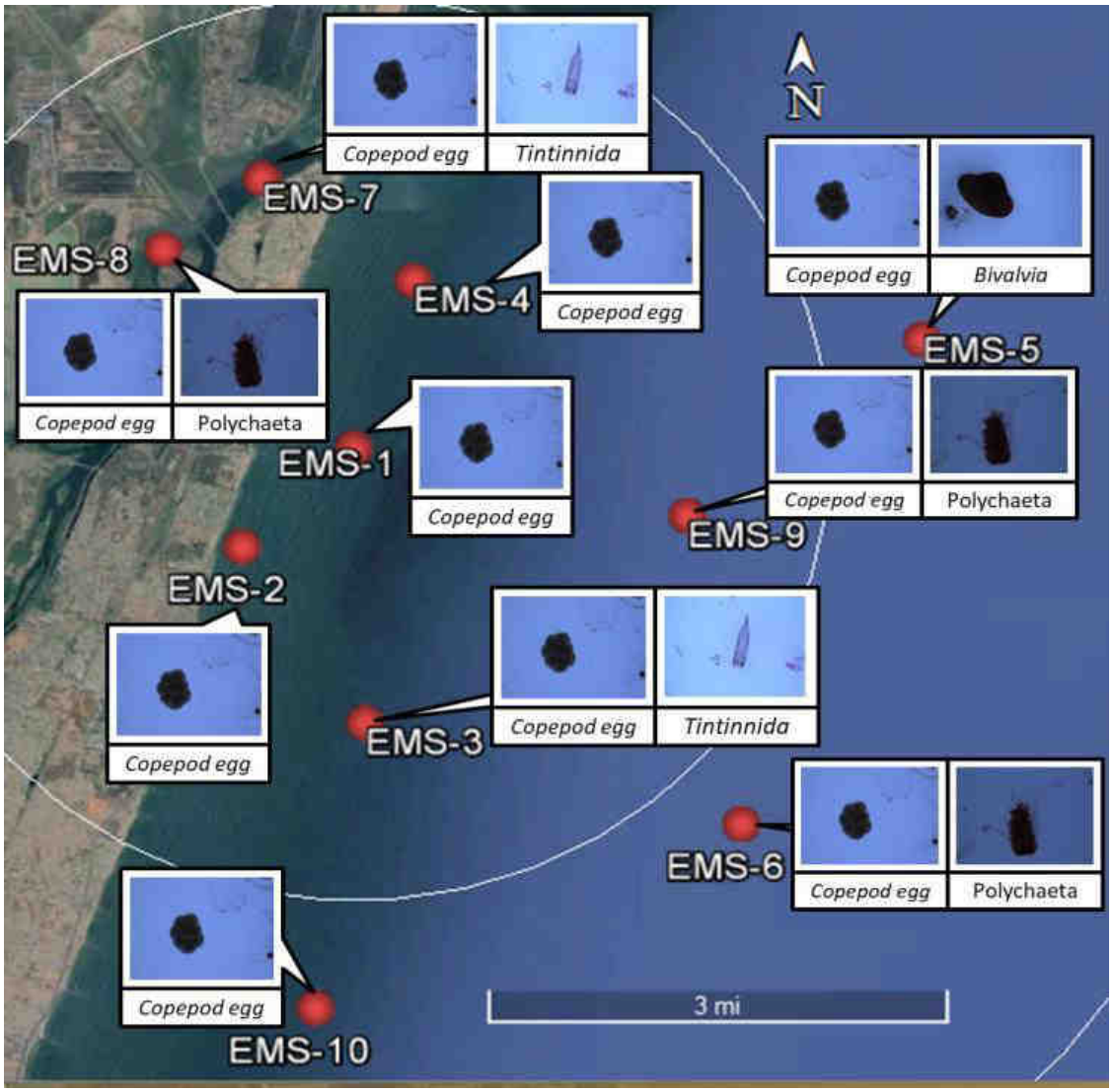
Acartia clausi | *Acartia* sp | *Acrocalanus* sp

Actinula larva (Cnidarian) | Bivalve veliger larvae | *Brachionus* sp (Rotifer)

		
Copepod egg	*Coreciousa typicus*	Echinopluteus larvae (of sea urchin and sand dollar)
Trochophore polychaete larvae	*Euterpina acutifrons*	*Evadne* sp.
Gastropod veliger larvae	*Microsetella* sp	Nauplius larvae
Nauplius larvae-Copepod	Oikopleura larvae	*Oithona nana*
Oithona sp	*Penilia* sp (Cladocera)	Polychaete larvae

Sagitta sp	Zoea larva	*Tintinnopsis corniger*

Figure 3-11Zooplankton recorded during Monitoring



Benthos

Depending upon their size, benthic animals are divided into three categories, microfauna, meiofauna and macrofauna. Benthic community responses to environmental perturbations are

useful in assessing the impact of anthropogenic perturbations on environmental quality. Macrobenthic organisms which are considered for the present study are animal species with body size larger than 0.5 mm. The macrofauna was constituted mainly by Foraminiferans, nematodes, bivalves, gastropods, Polychaetes and Ostracods

The total number of faunal groups varied from 3 (Station 3) to 4 (Station 5, &6). Overall about 6 groups of intertidal macrobenthos were recorded in the study area during the present investigation. The benthic community indicates variations in the faunal standing stock in the region and no clear trend in the distribution is discernible suggesting patchiness in the distribution of subtidal macrobenthos.

Composition

During present study macro benthos community in all the stations were mainly dominated by Nematodes (avg. % composition 24.17) followed by Foraminiferans (avg. % composition 19.81) Polychaetes (average percentage composition 19.71), Bivalvia (avg. % composition 17.57) Gastropods (avg. % composition 10.97) and Ostracods (avg. % composition 7.77). Distribution of Benthos in the study area is given in

Table 3-16**.**

Hierarchy of the Benthos

Nematodes >Foraminiferans > Polychaetes > Bivalvia > Gastropods > Ostracods

Table 3-16 Distribution of Benthos in the study area

S. No	Group (Nos./m^2)	Stations									
		MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10
1	Foraminiferans	23	56	34	11	23	23	0	0	11	23
2	Ostracods	0	0	0	23	0	0	34	23	0	0
3	Nematodes	23	34	11	23	0	0	45	67	23	23
4	Polychaetes	34	11	11	0	23	34	0	0	34	56
5	Bivalvia	34	0	23	0	23	11	23	11	45	11
6	Gastropods	11	23	11	11	0	0	34	0	23	0

Figure 3-12Benthos Images recorded during observation

Foraminiferan	Nematode	*Bivalve*

3.9 Statistical Analysis

Diversity Index

Following indices were used for estimation of ecological status of this area

1. Shannon's index
2. Margalef's index
3. Simpson's index

The indices were applied to phytoplankton, zooplankton and benthos.

Shannon' Index

Typically the value of the index ranges from 1.5 (low species richness and evenness) to 3.5 (high species evenness and richness), though values beyond these limits may be encountered. Because the Shannon Index gives a measure of both species numbers and the evenness of their abundance, the resulting figure does not give an absolute description of a sites biodiversity. It is particularly useful when comparing similar ecosystems or habitats, as it can highlight one example being richer or more even than another. There is always the need to inspect the data or use another index to unpack the true reasons for the difference.

$$H' = -\sum_{i=1}^{S}(p_i \ln p_i)$$

Where: where S is the total number of species and p_i is the frequency of the *i*th species. Average value of Shannon's index of phytoplankton community in the present study was observed to be 3.103 (**Table 3-17**), while that of zooplankton community is 1.55 (**Table 3-18**).Hence, the phytoplankton and zooplankton diversity of this area is very moderate.

Margalef's Index

It is calculated from the total number of species present and the abundance or total number of individuals.

Margalef Index (D) = S – 1/ log e N

Where: S – total number of species

N – total number of individuals

The higher the index the greater is the diversity. Average value of Margalef's index for phytoplankton was observed to be 6.473 while that of zooplankton was 1.997.

Simpson's Index

Simpson's Index measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species).

Simpson's Index$\lambda = \sum n(n-1)/N(N-1)$

Where: n – total individuals of each species

N – total individuals of all species

With this index, 0 represents infinite diversity and 1, no diversity. That is, the bigger the value of D, the lower the diversity. This is neither intuitive nor logical, so to get over this problem, D is often subtracted from 1 to give:

Simpson's Index of Diversity $1 - \lambda$

The value of this index also ranges between 0 and 1, but now, the greater the value, the greater the sample diversity. This makes more sense. In this case, the index represents the probability that two individuals randomly selected from a sample will belong to different species. Simpson index values of phytoplankton and zooplankton are very close to 1 (0.943 and 0.639 respectively) phytoplankton indicating high diversity whereas zooplankton shows moderate diversity.

Table 3-17 Diversity Indices for Phytoplankton community

Sample	Taxa_S	Simpson_1-D	Shannon_H	Evenness_ e^H/S	Margalef
MS 1	32	0.947	3.208	0.773	6.906
MS 2	29	0.947	3.122	0.783	6.27
MS 3	30	0.946	3.147	0.776	6.528
MS 4	29	0.933	2.995	0.689	6.27
MS 5	28	0.943	3.052	0.756	6.061
MS 6	32	0.941	3.122	0.709	6.996
MS 7	30	0.949	3.191	0.811	6.528
MS 8	29	0.942	3.089	0.757	6.319
MS 9	29	0.941	3.052	0.73	6.303

Sample	Taxa_S	Simpson_1-D	Shannon_H	Evenness_ e^H/S	Margalef
MS 10	30	0.94	3.049	0.703	6.545
Avg.	**29.8**	**0.943**	**3.103**	**0.749**	**6.473**

Table 3-18 Diversity Indices for Zooplankton community

Sample	Taxa_S	Simpson_1-D	Shannon_H	Evenness_ e^H/S	Margalef
MS 1	10	0.650	1.554	0.473	1.972
MS 2	9	0.701	1.606	0.554	1.757
MS 3	10	0.681	1.655	0.523	1.967
MS 4	10	0.637	1.545	0.469	1.976
MS 5	11	0.731	1.811	0.556	2.191
MS 6	9	0.675	1.609	0.555	1.761
MS 7	10	0.602	1.461	0.431	1.976
MS 8	11	0.626	1.546	0.427	2.191
MS 9	10	0.573	1.388	0.401	1.976
MS 10	11	0.517	1.327	0.343	2.201
Avg.	**10.1**	**0.639**	**1.55**	**0.473**	**1.997**

Intertidal Zone

The intertidal zone close to shore is characterized by sandy beaches, creeks and mudflats. Occurrence of mangrove species was observed along the side of Korattaliyar River mouth fish landing jetty and near over-bridge area, 2 species of mangroves were observed viz. *Avicennia marina* are dense and *Rhizophora mucaranata*.The density and diversity of the mangroves is distinctly lower in the smaller creeks. Along the smallest creeks true mangroves are present; adjoining areas instead coastal runner *Ipomea pes-caprae* and associates *Sesuvium portulacastrum* and non-mangrove halophytes are present.

Figure 3-13 Diversity in Intertidal zones

Avicennaia marina	*Rhizophora mucoranata*
Mangrove associates *Sesuvium partulacastrum*	Coastal runner *Ipomea pes-caprae*

Diversity of crabs in Ennore Coast

Crabs are one of the important faunal communities serving as very good food source to human beings in the marine and brackish water ecosystems. They are predacious carnivores and scavengers and playing an important role in detritus formation, recycling of nutrients and overall dynamics of ecosystems. An attempt has been made to list the brachyuran crabs along the Ennore Coast and nearby creeks of the study area. The study area, mainly the coastal, mud flats and the mangroves was surveyed at random for crab observation. Two type of crabs fiddler and the sand crab, *Ocypode platytarsis* given in the **Figure 3-14.**

Figure 3-14 Identification of crabs

Fiddler crab

Ocypode platytarsis

Diversity of Molluscan Fauna along Ennore Coast

The largest and most diverse Phylum in the tropical seas is Molluscs. The molluscs are soft - bodied, heterogenous group of animals with great antiquity and diversity. The majority of molluscs inhabit marine biotopes and they occur from the backwater zone, mangroves, intertidal, shelf and down to deeper waters. The ecological assessment revealed a total of 10 species of molluscs were collected and identified during the coastal micro-level walk through along the Ennore Coast carried out on 14th May 2019 and the observation location and its coordinates are given in the**Table 3-19.** The coastal survey points are given in**Figure 3-15.** Diversity of Molluscs along the Ennore coast is illustrated in**Figure 3-17.**

Table 3-19 Coastal Observation Coordinates

Observation Location	Latitude	Longitude
CW 1	13° 8'27.93"N	80°17'58.46"E
CW 2	13° 9'0.57"N	80°18'12.94"E
CW 3	13° 9'16.85"N	80°18'20.05"E
CW 4	13°10'24.05"N	80°18'46.09"E
CW 5	13°10'54.83"N	80°18'58.09"E
CW 6	13°13'25.59"N	80°19'43.68"E
CW 7	13°13'37.00"N	80°19'47.72"E
CW 8	13°13'57.39"N	80°19'4.71"E

Figure 3-15Coastal Walk Survey Points

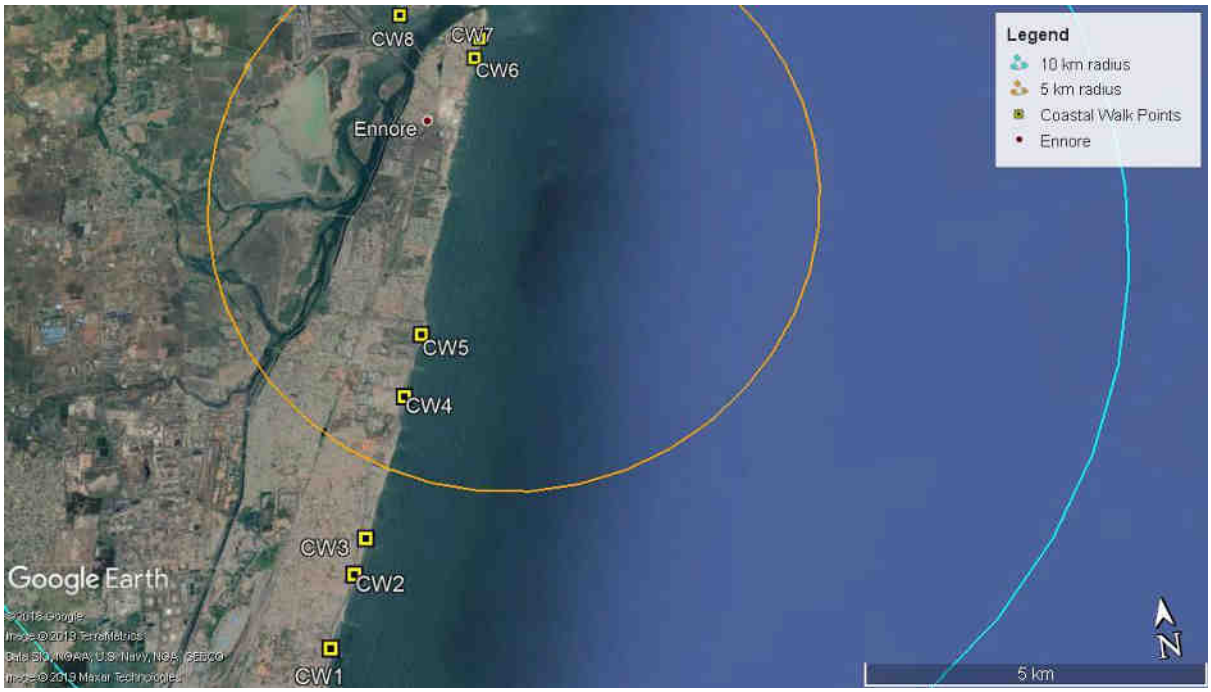


Figure 3-16 Diversity of Molluscs along the Ennore coast

Species Name	Dorsal	Ventral
Anadara sp		
Babylonia spirata		

Species Name	Dorsal	Ventral
Chicoreus virgineus		
Cypraea cicercula (Pustularia)		
Donax scortum		
Perna viridis		
Rapana rapiformis		

Species Name	Dorsal	Ventral
Tonna dolium		
Turritella sp		
Vasticardium sp		

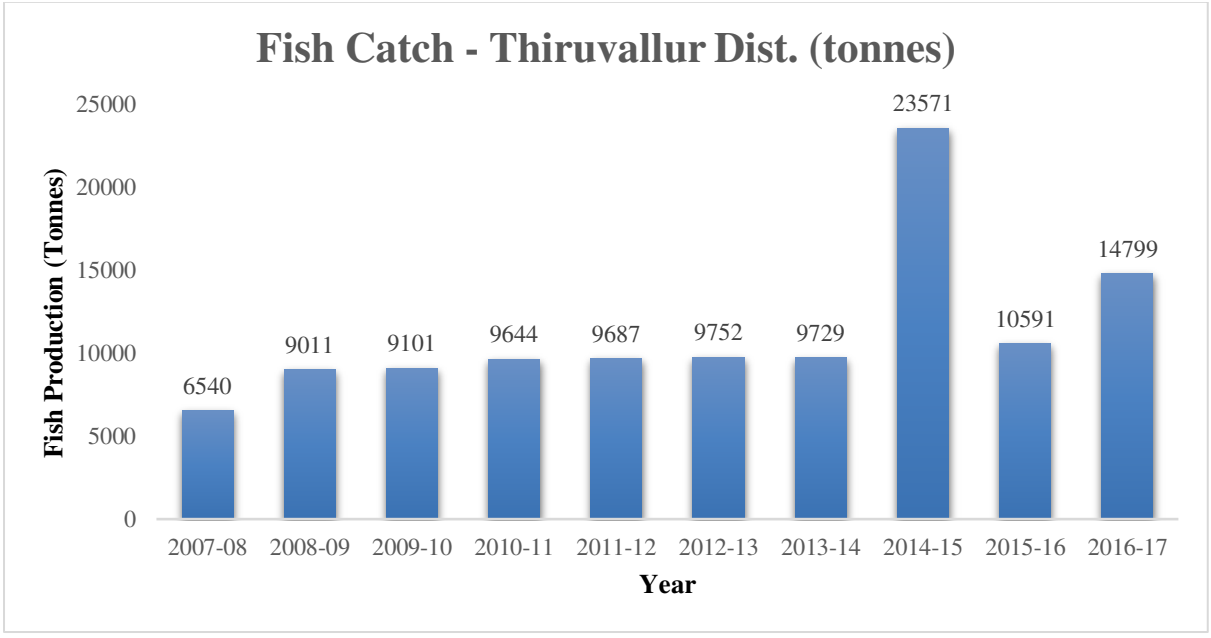
3.10 Fish Potential Catch

Indian National Centre for Ocean Information Services (INCOIS), an autonomous body under the Ministry of Earth Sciences, Govt of India has classified approximately 586 potential fishing zones along the coast of India. As per this map, Ennore falls under the potential fish catch zone. The potential fishing zones as marked by INCOIS has been shown in **Figure 3-17.**

Yearwise Fish catch data of Thiruvallur District is presented in **Figure 3-18.**

Figure 3-17 Map showing the Fish Potential Zones of India

Figure 3-18 Yearwise Fish catch data of Thiruvallur District



Source: *Commissioner of Marine Fisheries, Chennai; *Assistant Director of Fisheries, Ponneri*

3.10.1 Common fish Species

The dominant fish groups found in the Ennore coastal waters are Seerfish (*Scomberomorus guttatus*), Little tuna (*Euthynnus affinis*), Ribbonfish (*Trichiurus lepturus*), Sardines (*Sardinella gibbosa*, S.longiceps), Russel's Scad (*Decapterus russelli*) and Indian mackerel

(Rastrelliger kanagurta)[7]. The list of fishes found in ennore coastal waters are represented in the **Table 3-20.**

Table 3-20 List of Marine Fisheries Species Reported in the Ennore Coast

S.No	Common Name	Scientific Name	Reference*
1	Areolated cod	Epinephelus areolatus	4
2	Arius	Tachysurus dussumieri	3
3	Asian green mussel	Perna viridis	2
4	Barracuda	Sphyraena jello	4
5	Black banded trevally	Seriolina nigrofasciata	4
6	Blackfinned triplespine	Triacanthus brevirost	3
7	Butterfish	Tachysurus jella	3
8	Cichild	Mozambique tilapia	3
9	Common mussel	Mytilus gravincia	1
10	Dusky-finned bulleye	Priacanthus hamrur	2
11	Flat head fish	Platycephalus biomacula	3
12	Flat head mullet	Mugil cephalus	2
13	Flower crab	Portunus pelagicus	1
14	Flower prawn	Penaeus semisulcatus	4
15	Fouling oyster	Crossosstrea madrasensis	5
16	Giant tiger prawn	Penaeus monodon	1
17	Grey mullet	Mugil cephalus	1
18	Guitar fish	Rhincobatus djeddensis	4
19	Hammer head shark	Sphyrna zygaena	4
20	Indian goat fish	Parupeneus indicus	4
21	Indian Squid	Loligo duvaucelii	4
22	Indian white prawn	Penaeus indicus	1
23	Javanese cow ray	Rhinoptera Javanica	4
24	Jelly fish	Rhopilema spp.	4
25	Large-headed ribbon fish	Trichiurus lepturus	4
26	Leatherskin	Scomberoides lysan	4
27	Long spine sea-bream	Argyrops spinifer	4
28	Longarm mullet	Liza cunnesius	3
29	Manalai Liza	Macrolepis	3
30	Marine shrimp	Parapenaeopsis stylifera	4
31	Mozambique tilapia	Oreochromis mossambica	1
32	Mud crab	Scylla serrata	3

[7]Nammalwar et al (2012)- "*Applications of Remote Sensing in the validations of Potential Fishing Zones (PFZ) along the coast of North Tamil Nadu, India*"- Indian Journal of Geo-Marine Sciences, Vol.42(3), June 2013,pp.283-292

S.No	Common Name	Scientific Name	Reference*
33	Oyster	Crassostrea madrasens	2
34	Pearspot cichild	Etrophus suratensis	3
35	Ponyfish	Leiogtiathus fasciatus	3
36	Pufferfish	Tetrodon immacutus	3
37	Ray-finned fish	Anguilla bicolar	3
38	Red Snapper	Lutjanus spp.	3
39	Ribbon fish	Lepturacanthus savala	4
40	Scad	Alepes mate	4
41	Sea Crab	Charybdis cruciata	2
42	Sea cucumber	Holothuria atra	4
43	Serrated flat head fish	Platycephalus serratus	3
44	Silver sillago	Silago sharma	4
45	Snout	Rhynchorhamphus marginatus	3
46	Sole	Cynoglossus macrolepidotus	4
47	Spade fish	Ephippus orbis	4
48	Tade mellet	Liza tade	2
49	Target fish	Terapon jarbua	2
50	Thread-fin bream	Nemipterus japonicus	4
51	Tiger prawn	Penaeus monodon	1
52	Walking catfish	Clarias batrachus	1

Source: Reference in Footnote[8]

[8] 1. Chitrarasu et al., 2013, "*Study on the Bioaccumulation of Heavy Metals in Commercially Valuable and Edible Marine Species of Ennore Creek, South India"*. Int J Pharm Bio Sci . 4(2): 1063 – 1069.
2.Jaikumar et al., 2013, "*Heavy Metal Concentration of Sea Water and Marine Organisms in Ennore Creek, Southeast Coast of India"*. The Journal of Toxicology and Health.103 (192-201).
3. James et al., 1986, "*Water Pollution and Fish Mortality in Ennore Estuary, Madras .Marine Fisheries Information Service*". Central Marine Fisheries Research Institute. Cochin. India
4. Nirmala et al., 1988, Marine fishes of India. Myleripalayam Piriv.,
5.*"Waste Assimilative Capacity Studies of Ennore Creek, 2004"*, Integrated Coastal and Marine Area Management Programme. Department of Ocean Technology. National Institute of Ocean Technology. Chennai.

4 POTENTIAL ENVIRONMENTAL IMPACT

4.1 Impacts of marine water and sediment Quality

4.1.1 Temperature and Salinity Outfall Dispersion Modelling

In order to study the impact of the thermal outfall on the marine environment, advection dispersion modelling study has been carried out using scientific tools (DELFT -3d) for the proposed 1 X 660 MW ETPS expansion project. Marine outfall dispersion modelling study was carried out for a capacity of 2x660MW (ETPS expansion unit and replacement unit) for studying the dispersion pattern of temperature and salinity at the existing outfall location.

The objectives of the hydrodynamic and advection dispersion study are

- To establish numerical models to study the hydrodynamics and dispersion for the proposed ETPS expansion of 1x660MW.
- To assess the impact of temperature and salinity on the marine environment due to increase in outfall discharge.

A three dimensional coupled hydrodynamic and dispersion modelling study was carried out to determine the circulation pattern in the sea which considers the current pattern and surface elevation of the study area. The modelling was carried out for 2x660MW unit with the combined sea water intake flow of 24000 m^3/hr and combined outfall discharge flow of 16000 m^3/hr. The details of the intake and outfall points are given in**Table 4-1.**

Table 4-1 Details of the Marine Intake and Outfall

Location	Marine Co-Ordinate	Temperature (°C)	Salinity (ppt)	Depth (m)	Volumetric Flow Rate (m^3/hr)		
					1x660 MW ETPS Replacement	1x660 MW ETPS Expansion	Combined Flow
Sea Water Intake	13°12'7.72"N 80°19'37.96"E	28	33	8.2	12000	12000	24000
Outfall Discharge	13°11'41.53"N 80°19'19.70"E	33	50	5.4	8000	8000	16000

4.1.2 Modelling Methodology

To study the temperature and salinity dispersion pattern of the marine outfall, advection dispersion modelling study was carried out using delft 3d numerical model. The study area of 20km stretch from the outfall discharge point is considered for the modelling (**Figure 4.1**).

The model was validated for the hydrodynamic parameters for a period of 30 days (two tidal cycle). Bathymetry data of the study area is prepared using General Bathymetry Chart of the Oceans (GEBCO) data and Marine wind pattern of the study area is adopted from European Centre for Medium Range Weather Forecasting (ECMWF). The average ambient temperature and salinity of marine sea water in the study area is considered from NODC World Ocean Atlas (2013). Tidal data of the study area is taken from TPXO 6.2 Global Inverse Tide Model.

Figure 4-1 Google Earth Image showing the Intake and Outfall Location

Source: Google Earth

4.1.3 Hydrodynamic and Dispersion Model

The coastal oceans are the most challenging marine environments as the scattering pattern is unsteady and not uniform. They are subjected to changes in bathymetry, irregular coastlines and are forced both internal, lateral and surface by a complex array of tidal, wind and buoyancy forces on a broad range of space/time scales. The resulting coastal circulation patterns include both persistent and time-variable fronts, intense currents with strong spatial dependence, coastal trapped waves, internally generated mesoscale variability, large horizontal water mass contrasts, strong vertical stratification and regions of intense turbulent mixing in both surface and bottom boundary layers. Numerical modelling of the world's

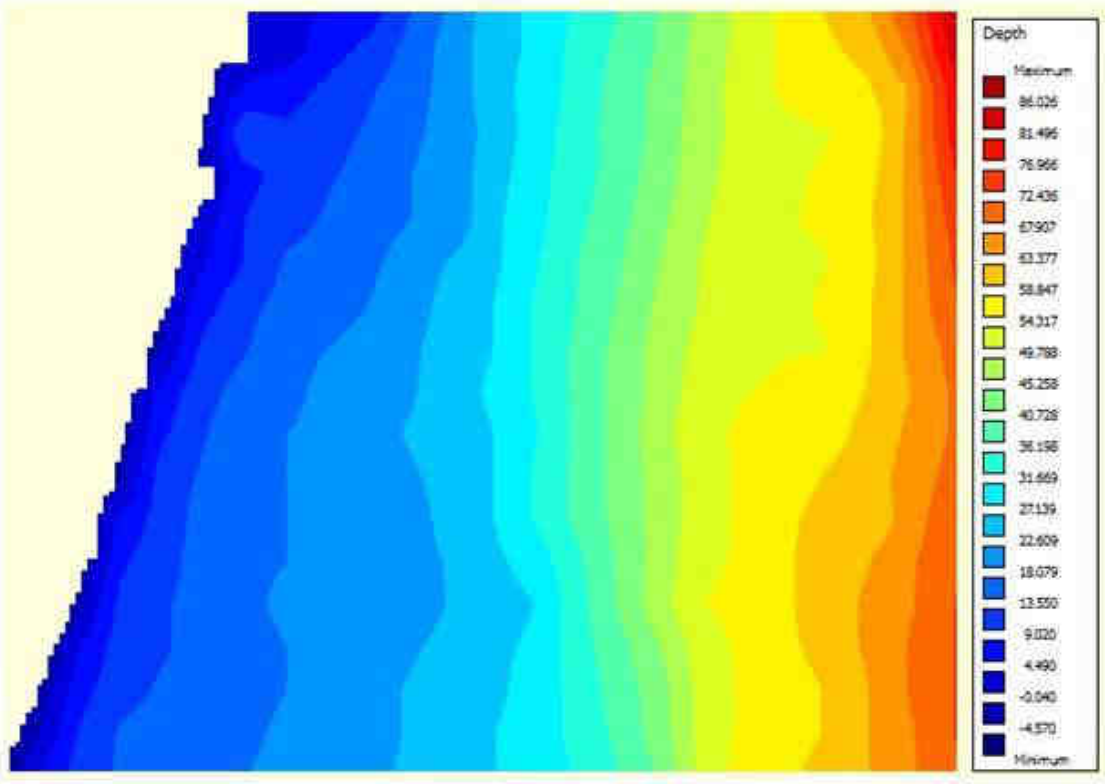
ocean clearly requires very flexible, highly optimized models of significant dynamical complexity. Recently, the models developed for lake and shelf-sea dynamics have become increasingly complex, and are now typically based on the fully non-linear stratified "primitive equations".

The scientific tool used for the current study is Delft-3d. Delft-3D is fully integrated computer software for a multidisciplinary approach and 3D computations for coastal, river and estuarine areas. It helps in understanding the wave-current interaction, hydrostatic flow(2D/3D), salinity, temperature, non cohesive/ cohesive sediment transport, morphology, particle tracking etc,. This model calculates the non-steady flow and transparent phenomena that results from the tidal and meteorological forcing on a rectilinear or a curvilinear boundary fitting grid. This is a sigma-coordinate model that follows the bottom topography. The input conditions include Bathymetry, temperature, Salinity, boundary conditions, initial conditions, forcing, time step, timeframe and numerical settings. The grid resolution is 10 m to 100 km.

4.1.4 Bathymetry

The bathymetry data for the modelling study has been collected from General Bathymetry Chart of the Oceans (GEBCO). The extracted bathymetry data is plotted using Delft-3D and shown in**Figure 4-2**. It has been observed that the model domain has a maximum depth of 60m and the depth near the shore is shallow ranging from 3m to 5m.

Figure 4-2 Bathymetry map of the study area



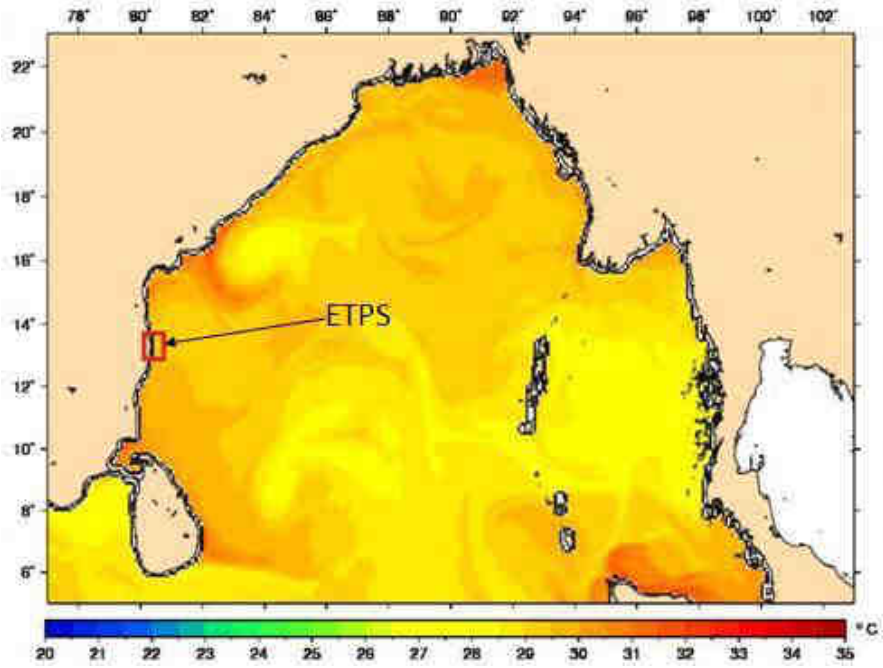
Source: General Bathymetry Chart of the Oceans

4.1.5 Temperature and Salinity

The temperature and Salinity data for the study area has been taken from the objectively analyzed mean of the NODC World Ocean Atlas (2013) with the resolution of 0.25º. Since the model domain has a maximum depth of 60 m and the depth near the outfall location ranges from 5 m to 6m which is shallow, the bottom temperature was found similar to the Surface temperature. With this consideration, it is taken that the study area has an ambient temperature of 28ºC in winter and North-East Monsoon whereas in summer and South-West Monsoon, the temperature is 30ºC. Similarly, the Salinity in winter and North-East Monsoon is 30ppt, whereas in Summer and South-West Monsoon the salinity is 33ppt.

As per the norms stated by CPCB (Central Pollution Control Board) the temperature of the outfall discharge should not be greater than 5ºC above ambient temperature. The salinity of the outfall discharge has been calculated using the mass balance equation considering the combined intake and outfall quantity. It is found to be 18ppt above ambient.

Figure 4-3 Temperature Plot of the study area



4.1.6 Other Physical Parameters

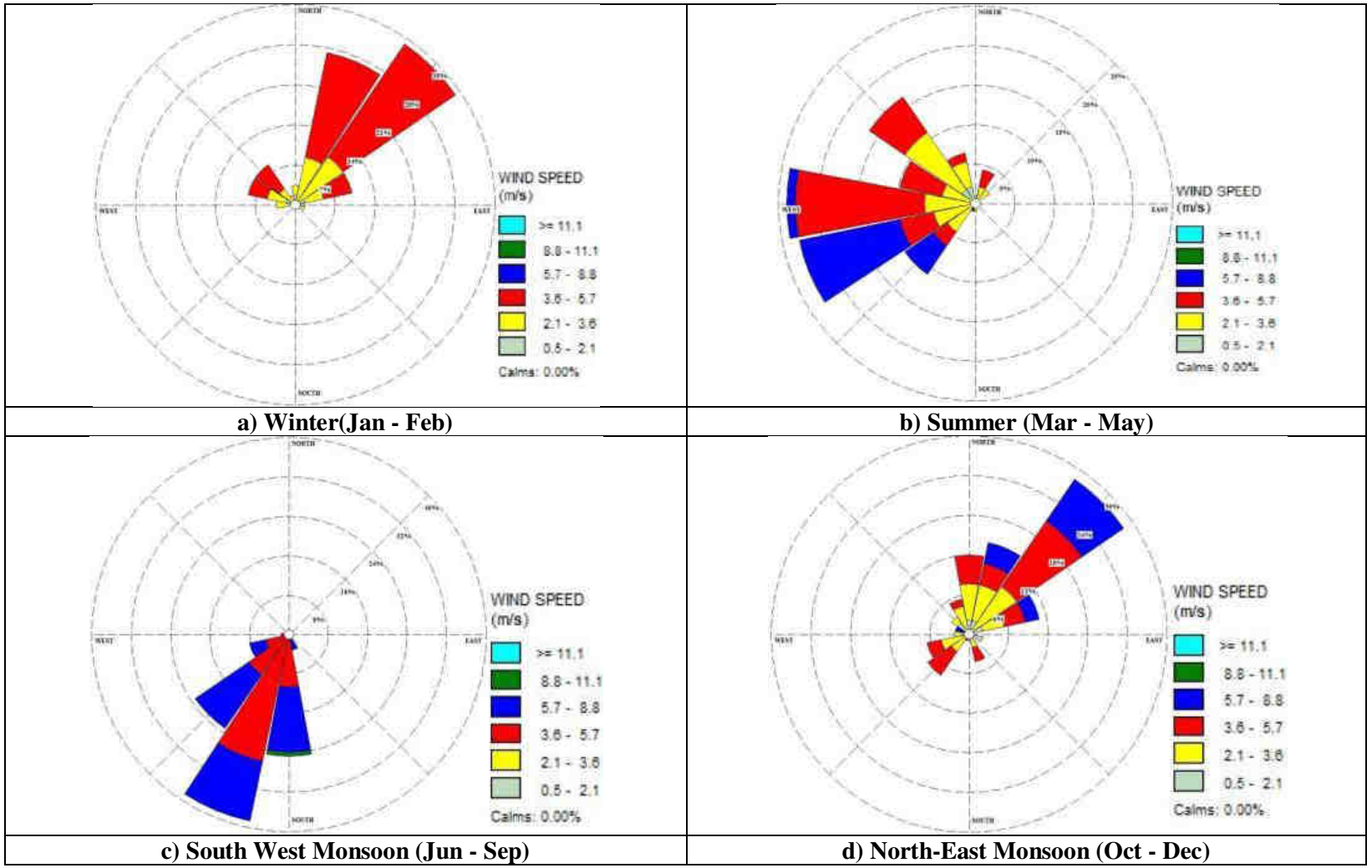
4.1.6.1 Wind

The wind data for the study area has been taken from the European Centre for Medium-Range Weather Forecast (ECMWF). Since the IMD wind data is available only for terrestrial region, the wind data for the coastal region/ocean is taken from ECMWF. The following wind parameter has been considered for Model simulation(**Table 4-2**). **Figure 4-4**and**Figure 4-5**shows the wind rose plot for the study area (ECMWF) and the wind rose plot for the nearby IMD station respectively. It has been observed from the wind rose plot that the wind pattern is almost same for both ECMWF and IMD.

Table 4-2 Wind Pattern in the Study Area

Season	Wind Speed (m/s)		Wind Direction	
	Minimum	Maximum	From	To
Winter	3.6	8.8	North-East	South-West
Summer	3.6	11.1	South-West	North-East
South West Monsoon	5.7	8.8	South-West	North-East
North East Monsoon	2.1	5.7	North-East	South-West

Figure 4-4 Seasonal Wind rose plot for the Study Area (ECMWF)



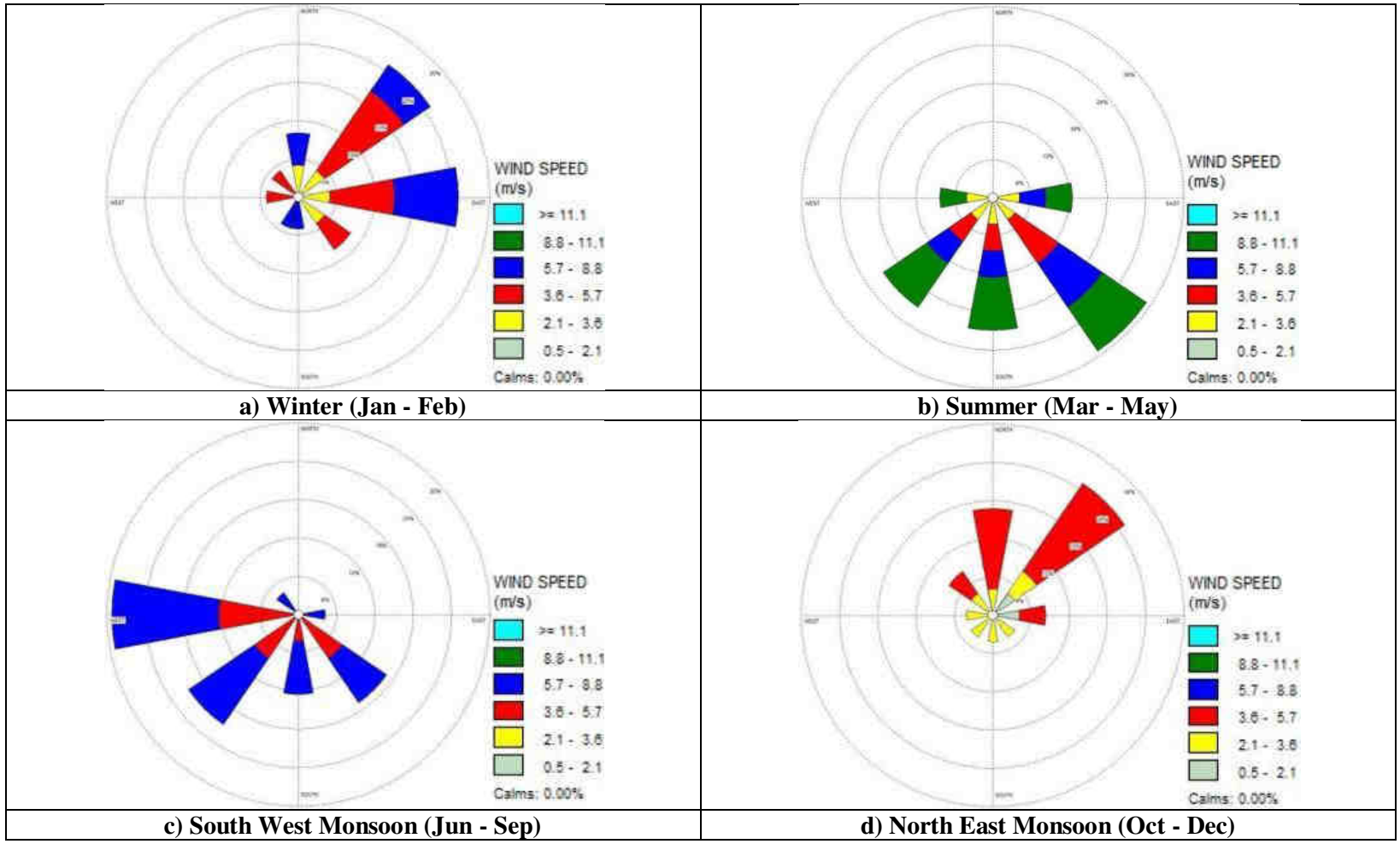
a) Winter(Jan - Feb)

b) Summer (Mar - May)

c) South West Monsoon (Jun - Sep)

d) North-East Monsoon (Oct - Dec)

Figure 4-5 Windrose plot of the nearest IMD Station (IMD-Chennai)[9]



a) Winter (Jan - Feb)

b) Summer (Mar - May)

c) South West Monsoon (Jun - Sep)

d) North East Monsoon (Oct - Dec)

[9] Climatological Normals (1971-2000) issued by Office of the Additional Director General of Meteorology(Research)- Indian Meteorological Department

4.1.6.2 Boundary Condition

Boundary conditions at the surface include specification of fluxes of momentum, heat and salt. At the ocean bottom, a quadratic drag formulation is used for momentum and the normal fluxes of heat and salt are typically set to zero. At closed lateral boundaries, the normal fluxes of heat and salt are also assumed to vanish. The seaward boundary tidal condition is the Astronomic constituents for water level and the lateral boundary tidal condition is the Neumann's time series.

4.1.7 Hydrodynamic Results

4.1.7.1 Ocean Currents

Ocean Current is a continuous, directed movement of seawater generated by forces acting upon this mean flow such as breaking waves, wind, the Coriolis Effect, temperature and salinity differences. Bathymetry, shoreline configurations and interactions with other currents influence a current's direction and strength. Ocean Currents play a major role in determining the climate of the region through which they travel.

The circulation features have been studied along the study area using initial, lateral and surface boundary conditions of the atmosphere and ocean parameters such as wind speed, sea temperature and salinity.

It has been observed that the study area has two major Currents. During winter and North-East monsoon the current flows from north-east to south-west with an average speed of 0.08m/s whereas in summer and south-west monsoon, the current gets reversed and flows from south-west to north-east with an average speed of 0.085m/s. The maximum current speed of 0.1m/s is recorded in summer which flows from South-West to North-East. **Table 4-3**gives the details of the current pattern in the Study area.

Table 4-3 Current Pattern in the Study Area

Season	Current Speed (m/s)		Current Direction	
	Maximum	Minimum	From	To
Winter	0.090	0.075	North-East	South-West
Summer	0.100	0.072	South-West	North-East
South West Monsoon	0.098	0.072	South-West	North-East
North East Monsoon	0.095	0.080	North-East	South-West

Figure 4-6 Area plot of the Seasonal Currents

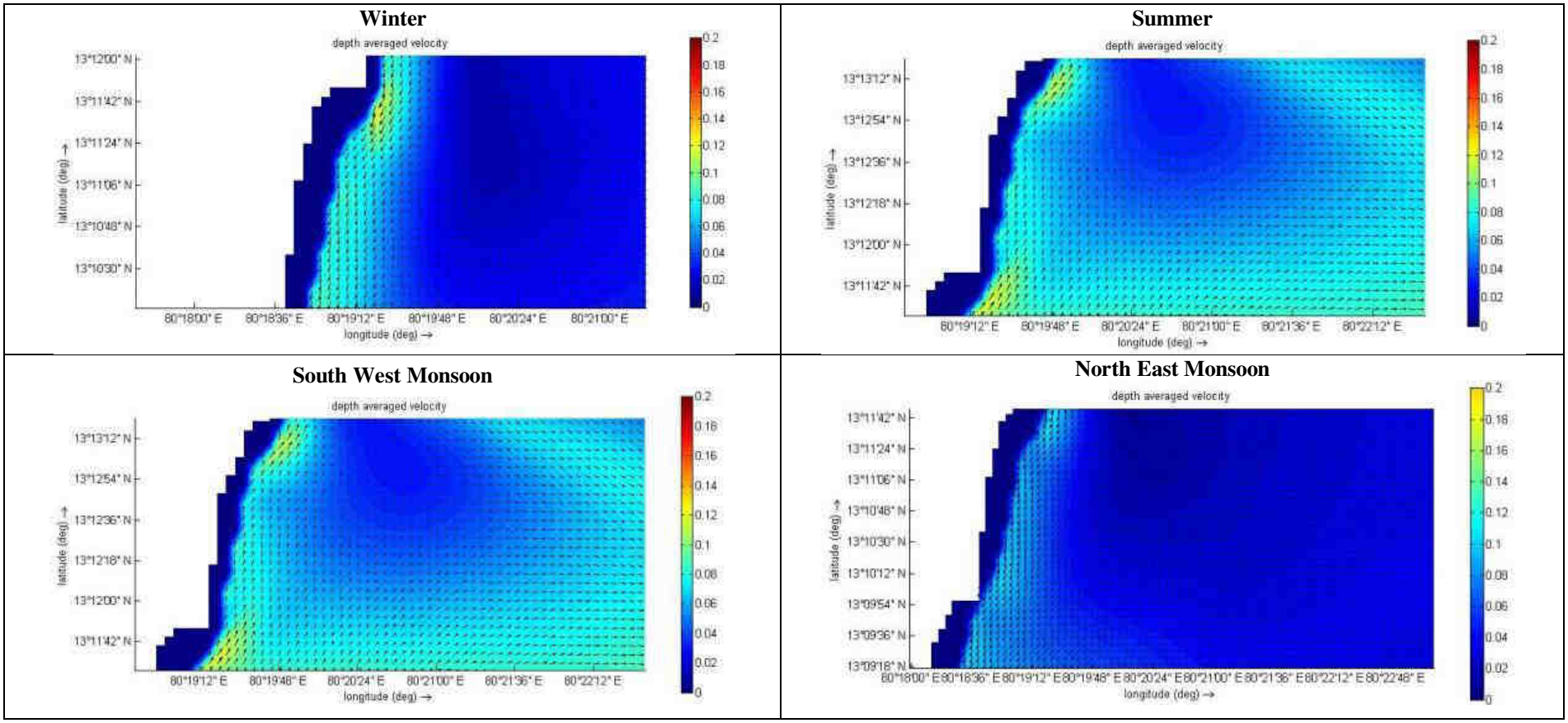
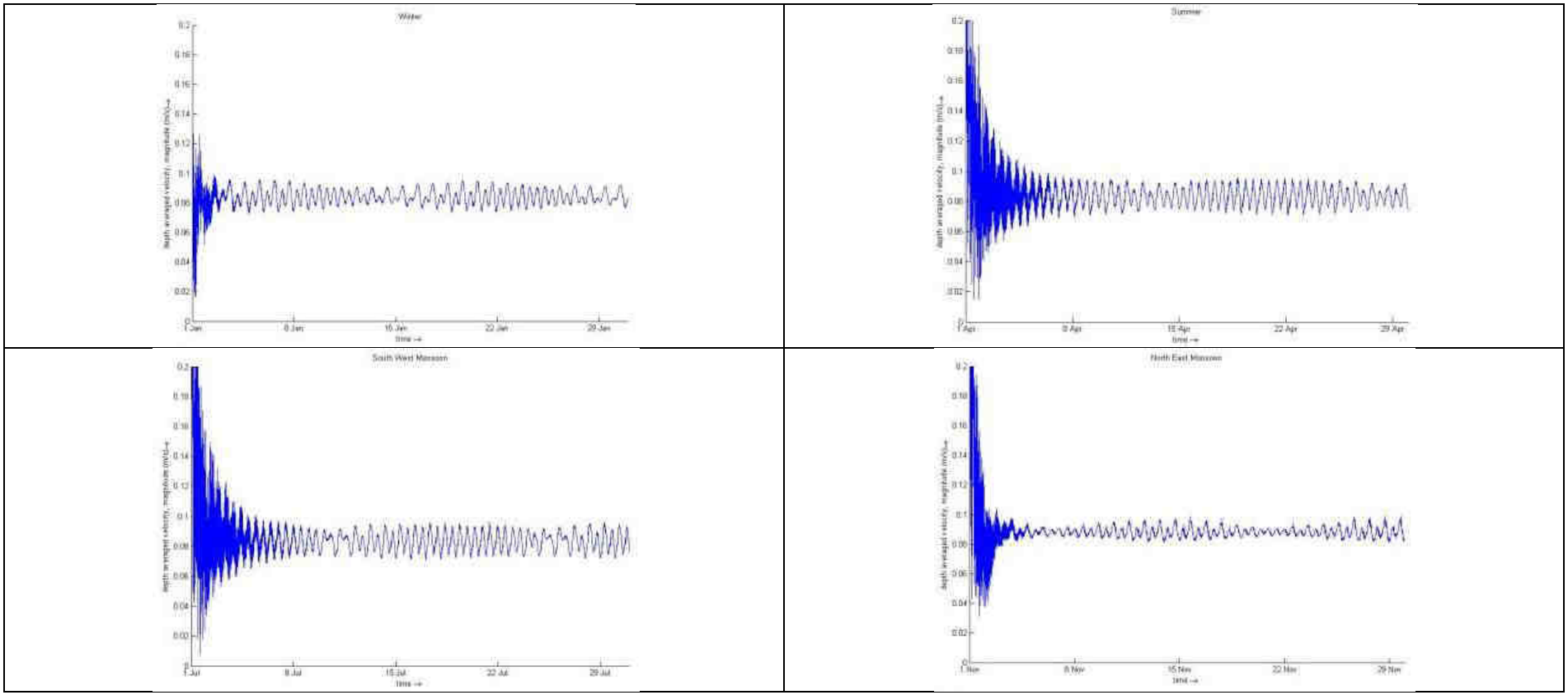


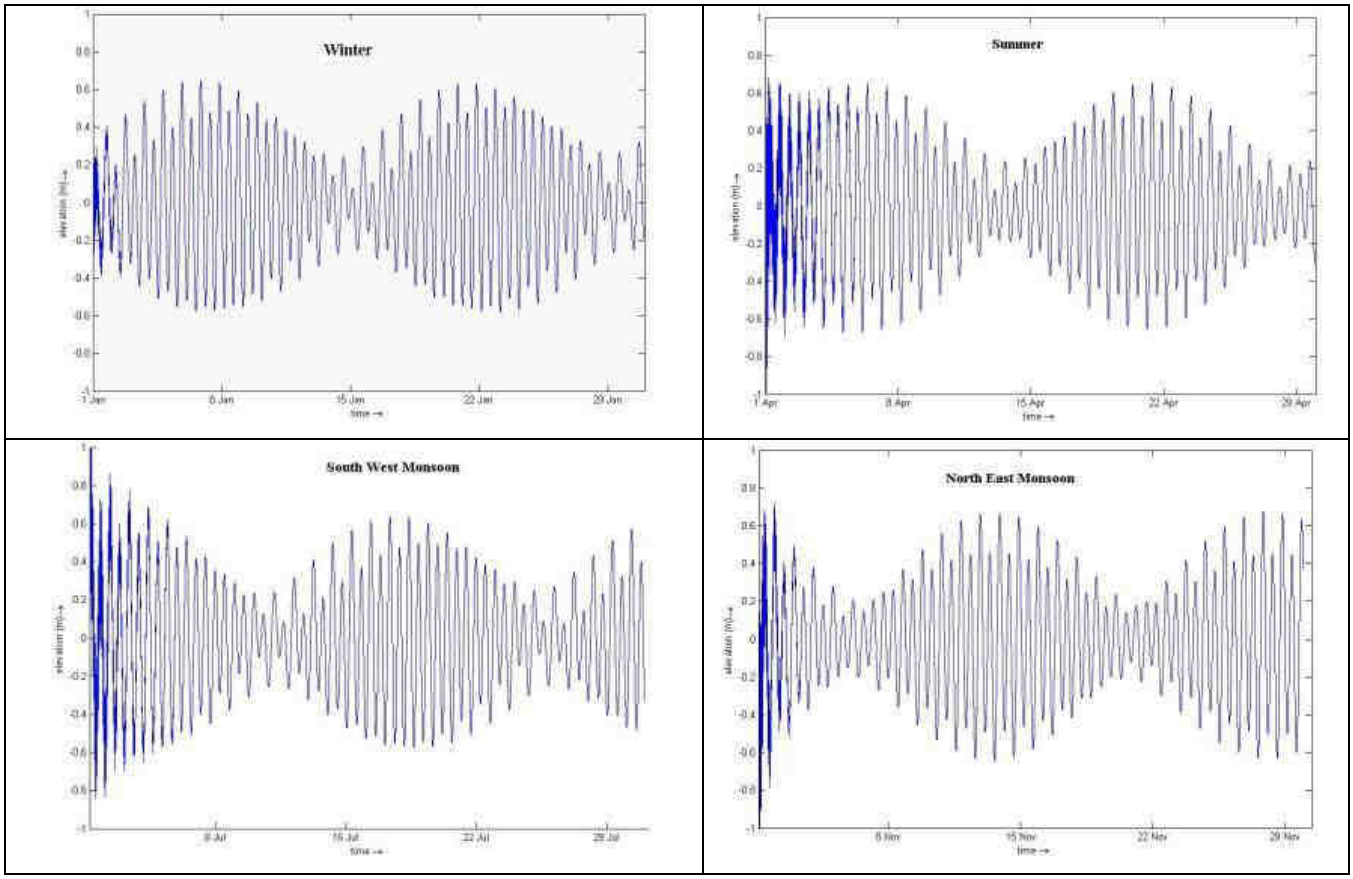
Figure 4-7 Time Series plot of the Seasonal Current



4.1.7.2 Tides

Tides are the rise and fall of sea levels caused by the combined effects of gravitational forces exerted by the Moon, Sun and Rotation of the Earth. The tidal pattern in the study area is semi-diurnal. Since it has two nearly equal high and low tides in a day. It is observed that the study area has a tidal variation of 0.8m to 1.2m.

Figure 4-8 Time Series plot of the Seasonal Tide



4.1.8 Dispersion Module Results

4.1.8.1 Temperature Dispersion

Advection Dispersion (AD) model study has been carried out for the combined sea water intake and outfall discharge of the 2x660MW (ETPS Expansion and Replacement Unit). The temperature dispersion pattern at the outfall points has been studied and presented below. **Table 4-4**presents the details of the Intake and Outfall.

Table 4-4 Details of Marine Intake and Outfall

Location	Marine Co-ordinates	Seasons	Temperature (°C)	Salinity (ppt)	Depth (m)	Distance from Shore (m)	Volume (m^3/hr)
Intake	13°12'7.72"N 80°19'37.96"E	Winter	28	33	8.2	650	24000
		Summer	31	36			
		SWM	30	35			
		NEM	30	35			
Outfall	13°11'41.53"N 80°19'19.70"E	Winter	33	51	5.4	250	16000
		Summer	36	54			
		SWM	35	53			
		NEM	35	53			

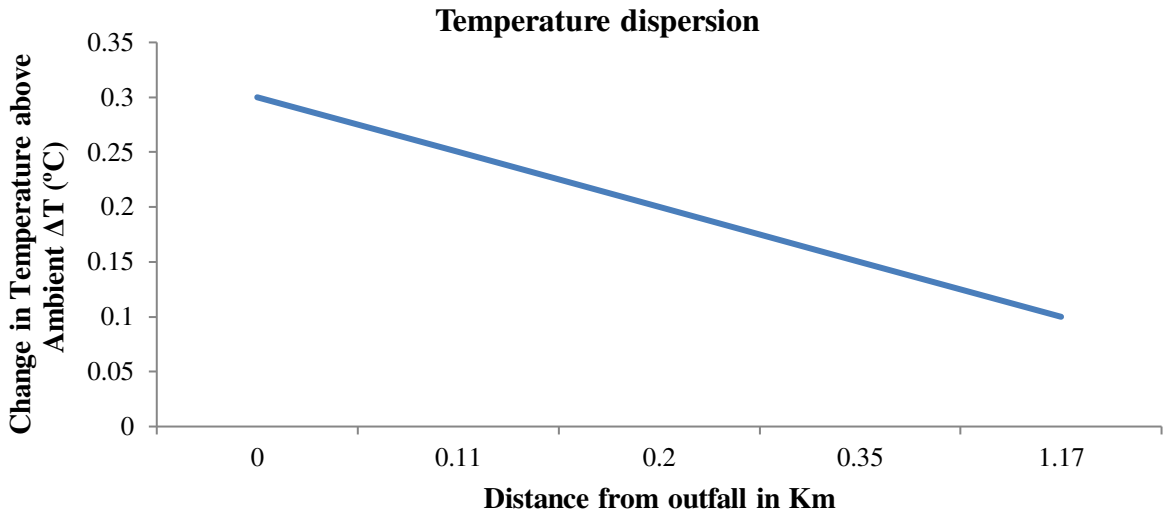
The model has been simulated for a period of thirty days in each season to view the pattern of thermal dispersion.

The maximum distance of thermal dispersion from the outfall location is around 1168m, beyond which the temperature drops less than 0.1°C from ambient temperature. The temperature variation at the intake location is insignificant throughout the year (all the season). The maximum variation of temperature at the intake point is 0.1°C from the ambient temperature which is observed at the intake point during summer and south-west monsoon. Hence there is no chance of recirculation of hot water. The maximum temperature variation of 0.2°C from ambient temperature is observed at the shore during the south-west monsoon.

Table 4-5 Summary of Temperature Dispersion

Seasons	Tidal Patterns		Distance of high concentration from outfall locations (m)	Temperature at Shore above ambient (℃)
Winter	Spring	Flood	720	0.11
		Ebb	1120	
	Neap	Flood	780	
		Ebb	920	
Summer	Spring	Flood	734	0.11
		Ebb	1105	
	Neap	Flood	794	
		Ebb	852	
South West Monsoon	Spring	Flood	730	0.23
		Ebb	1156	
	Neap	Flood	776	
		Ebb	831	
North East Monsoon	Spring	Flood	901	0.04
		Ebb	1168	
	Neap	Flood	919	
		Ebb	1084	

Figure 4-9 Graph showing the distance of temperature dispersion



The spatial plots of the temperature dispersion for three seasons are presented in **Figure 4-10,Figure 4-11, Figure 4-12 and Figure 4-13**.

Figure 4-10 Area plot for Season Temperature Dispersion – Spring Flood

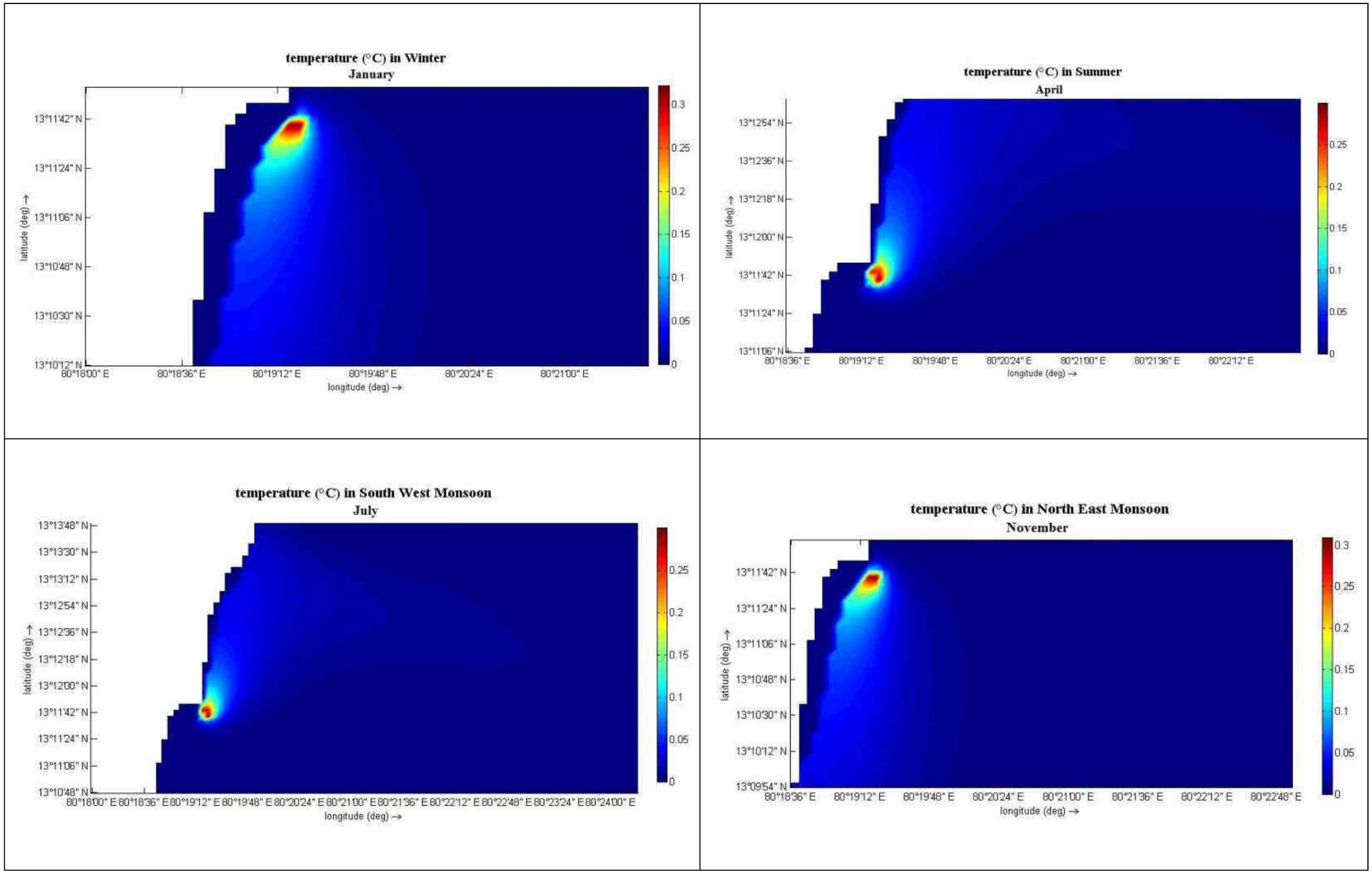


Figure 4-10shows the area plot of seasonal temperature dispersion during Spring-Flood. The distance of high temperature zone falling within 0.1ºC above ambient temperature for winter, Summer, South West Monsoon and North East Monsoon from the outfall location of the power plant are about 720m, 734m, 730m, &901m respectively.

Figure 4-11 Area plot for Seasonal Temperature Dispersion – Spring Ebb

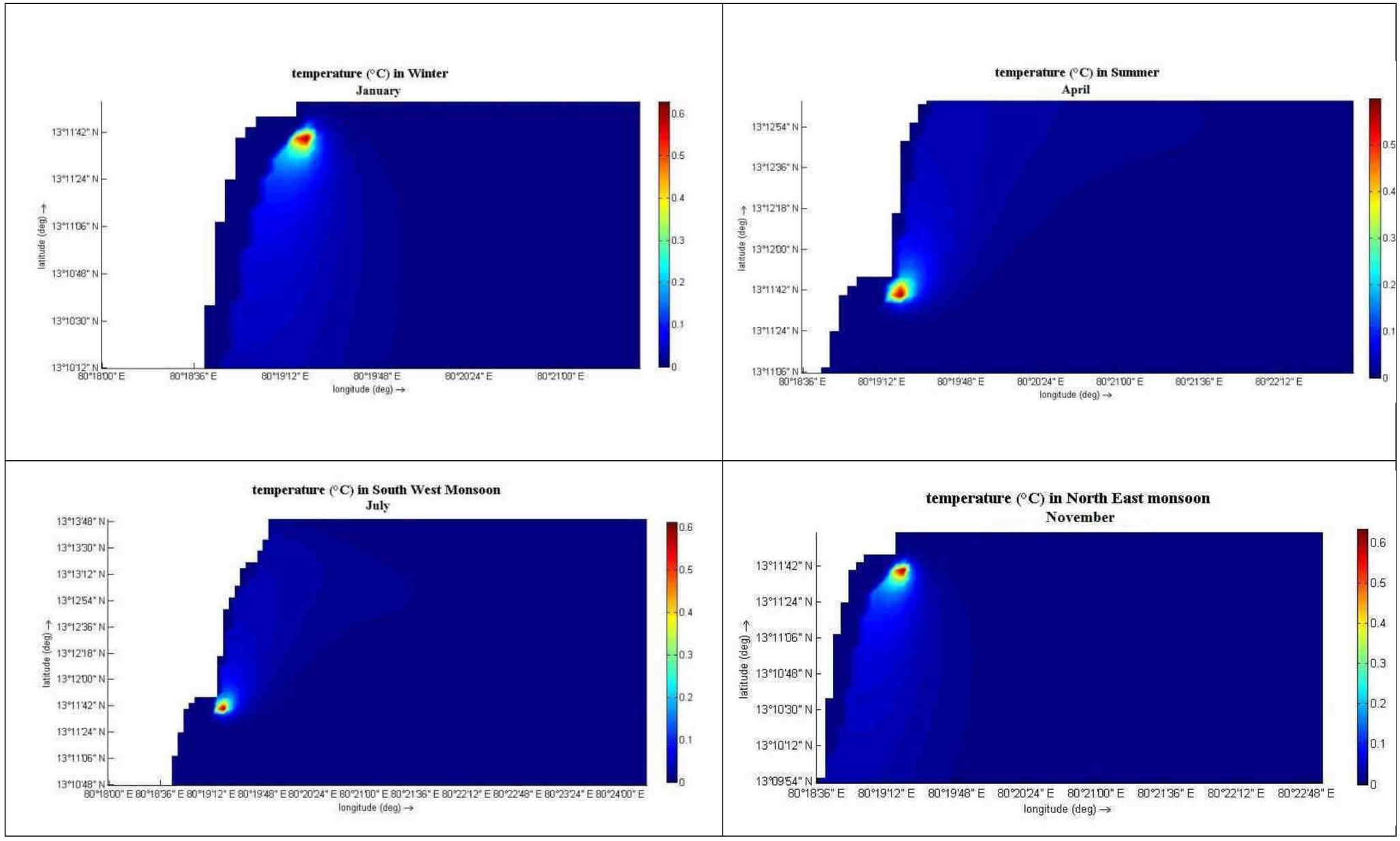
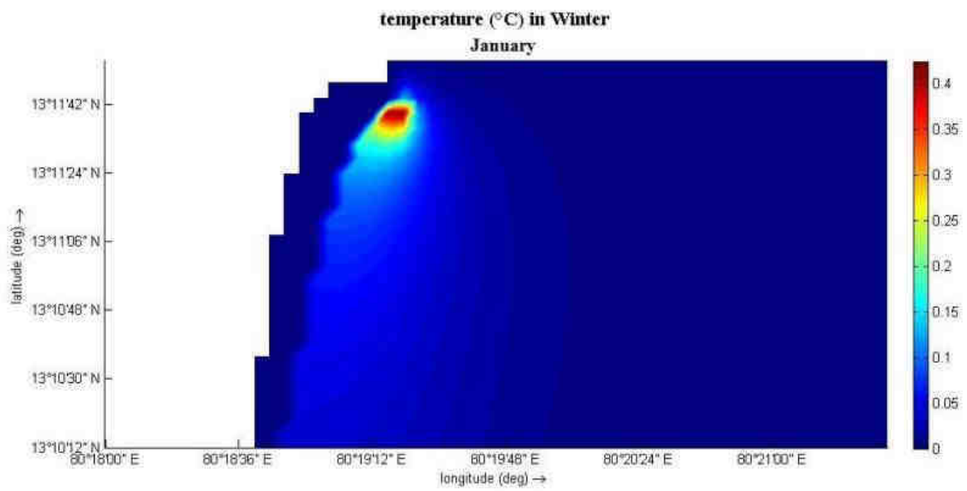
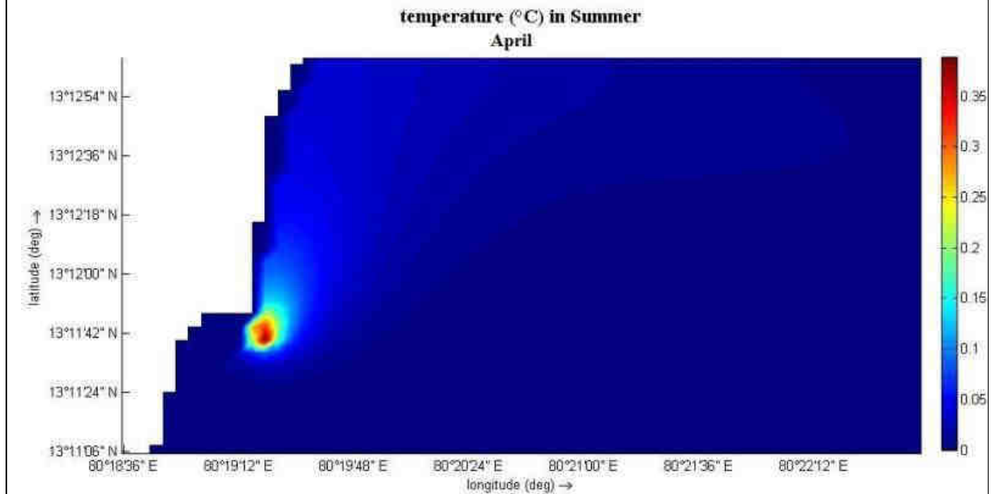
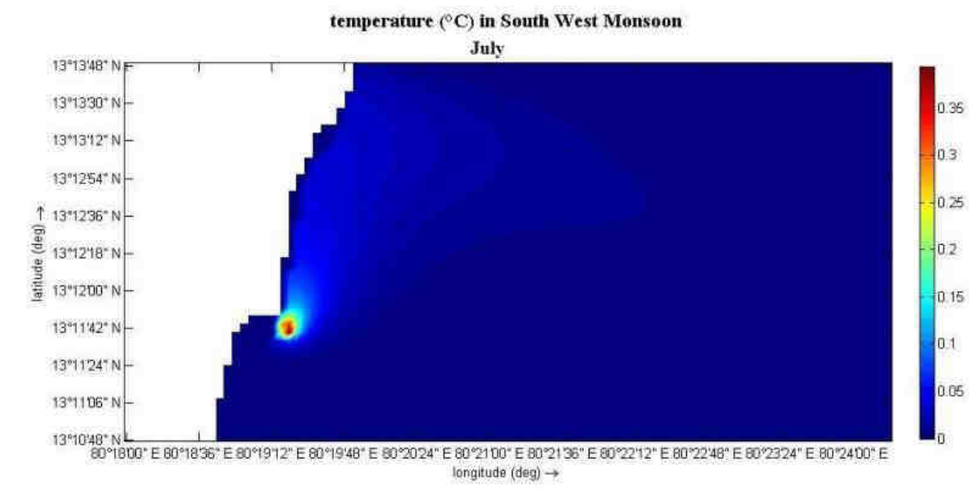


Figure 4-11shows the area plot of seasonal temperature dispersion during Spring-Ebb. The distance of high temperature zone falling within 0.1ºC above ambient temperature for winter, Summer, South West Monsoon and North East Monsoon from the outfall location of the power plant are about 1120m, 1105m, 1156m, and 1168m respectively.

Figure 4-12 Area plot for Seasonal Temperature Dispersion – Neap Flood







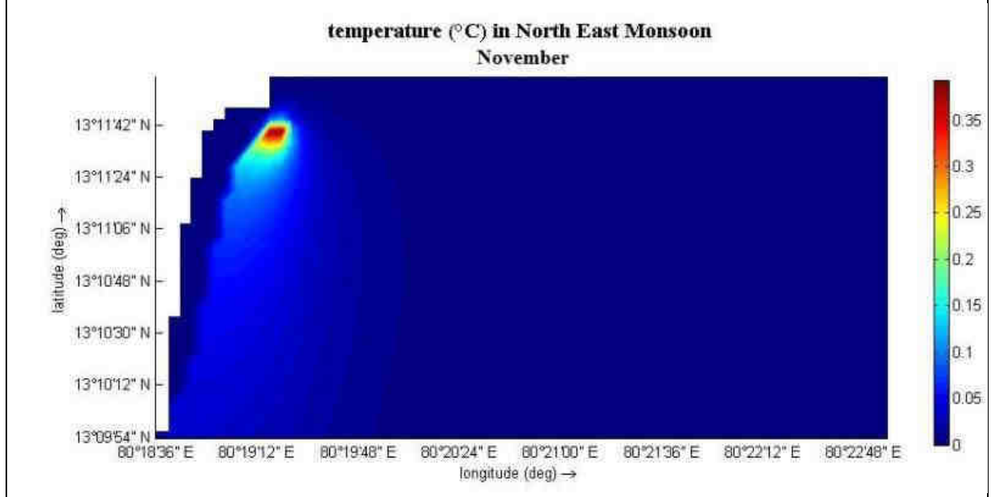
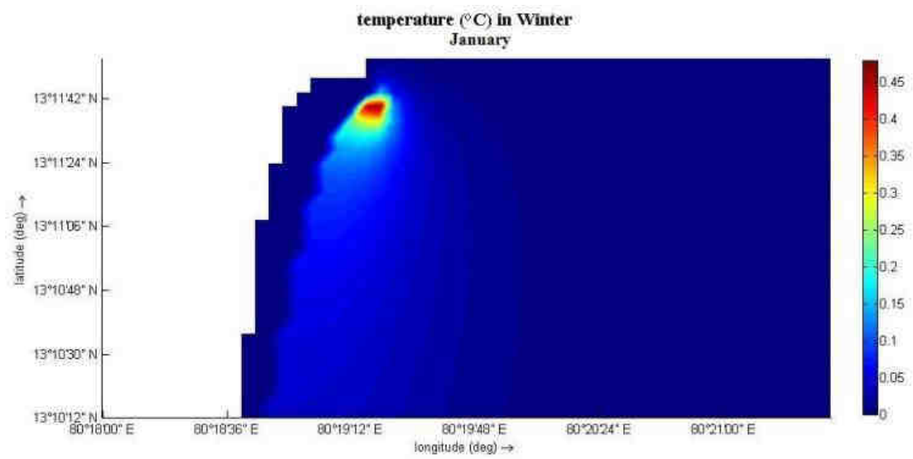
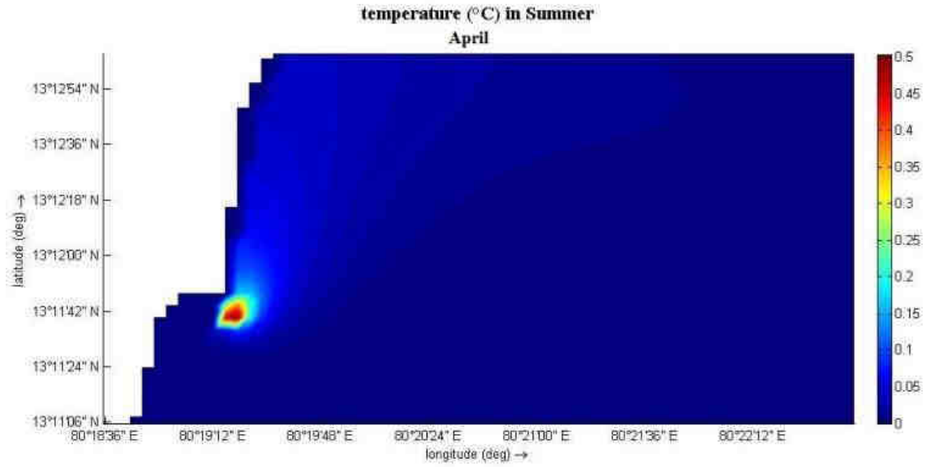
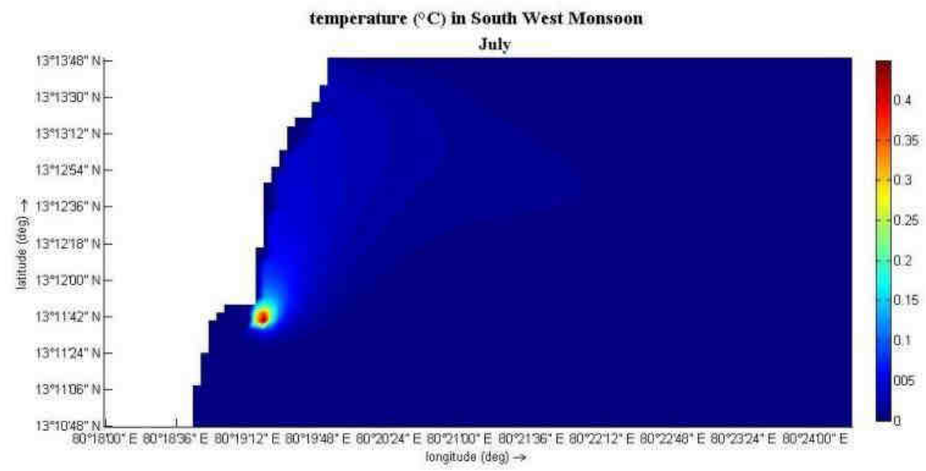


Figure 4-12shows the area plot of seasonal temperature dispersion during Neap-Flood. The distance of high temperature zone falling within 0.1ºC above ambient for winter, Summer, South West Monsoon and North East Monsoon from the outfall location of the power plant are about 780m, 794m, 776m, and 919m respectively.

Figure 4-13 Area plot for Seasonal Temperature Dispersion – Neap Ebb







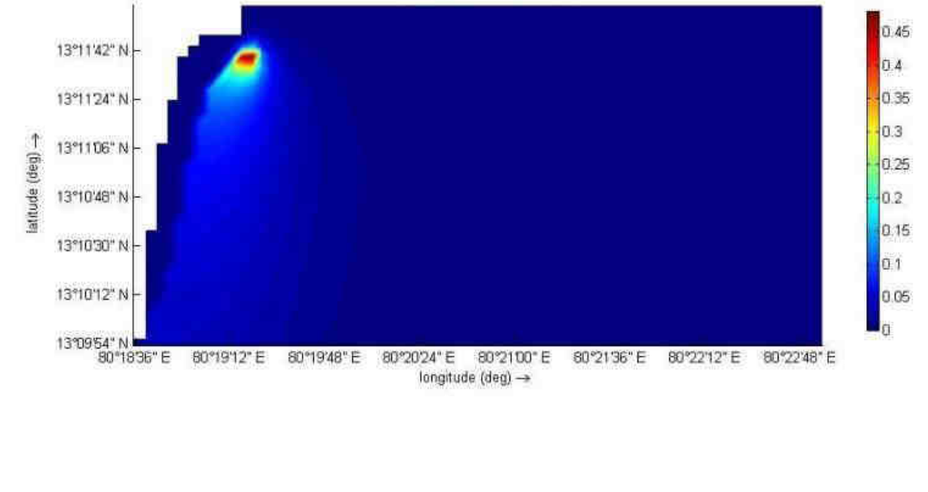


Figure 4-13shows the area plot of seasonal temperature dispersion during Neap-Ebb. The distance of high temperature zone falling within 0.1ºC above ambient for winter, Summer, South West Monsoon and North East Monsoon from the outfall location of the power plant are about 920m, 852m, 831m, and 1084m respectively.

4.1.9 Salinity Dispersion

The model has been simulated for a period of thirty days in each season to view the pattern of salinity dispersion. The below figure help in understand the scenario better.

The maximum distance of salinity dispersion from the outfall location is around 890m, beyond which the salinity level drops less than 0.5ppt from ambient salinity. The salinity variation at the intake location is insignificant throughout the year. The maximum variation of salinity at the intake location is 0.18ppt above ambient salinity. Hence there is no chance for recirculation of high saline water. The maximum salinity variation of 0.7ppt from ambient salinity is observed at shore during south west monsoon. The spatial plots of the salinity dispersion for three seasons are presented in **Figure 4-15, Figure 4-16, Figure 4-17 and Figure 4-18.**

Table 4-6 Summary of Salinity Dispersion

Seasons	Tidal Patterns		Distance of high concentration from outfall locations (m)	Salinity at Shore above ambient (˚ppt)
Winter	Spring	Flood	632	0.45
		Ebb	891	
	Neap	Flood	662	
		Ebb	735	
Summer	Spring	Flood	498	0.4
		Ebb	781	
	Neap	Flood	540	
		Ebb	614	
South West Monsoon	Spring	Flood	482	0.6
		Ebb	840	
	Neap	Flood	564	
		Ebb	740	
North East Monsoon	Spring	Flood	569	0.14
		Ebb	790	
	Neap	Flood	616	
		Ebb	755	

Figure 4-14 Graph showing the distance of salinity dispersion

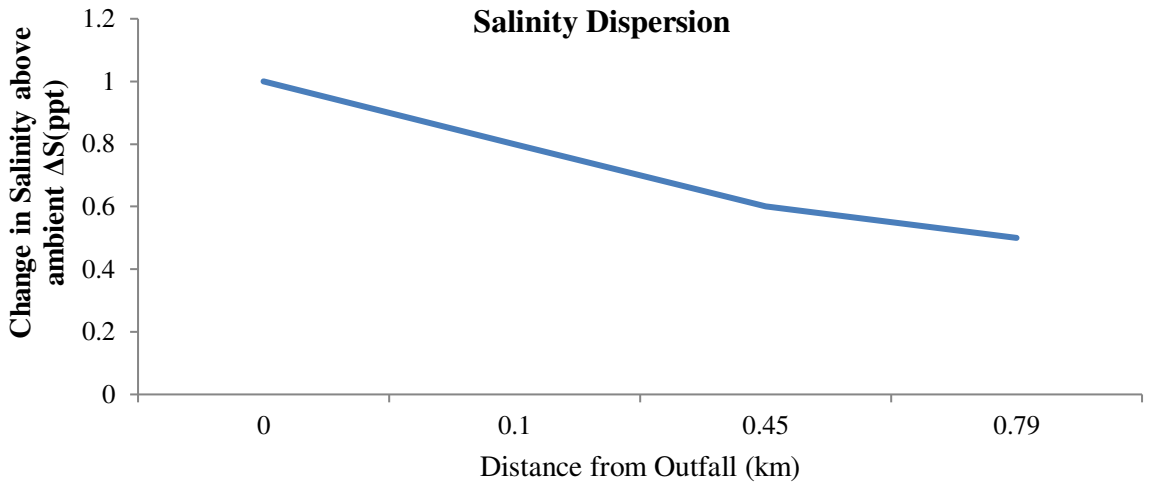


Figure 4-15 Area plot for Seasonal Salinity Dispersion during Spring flood

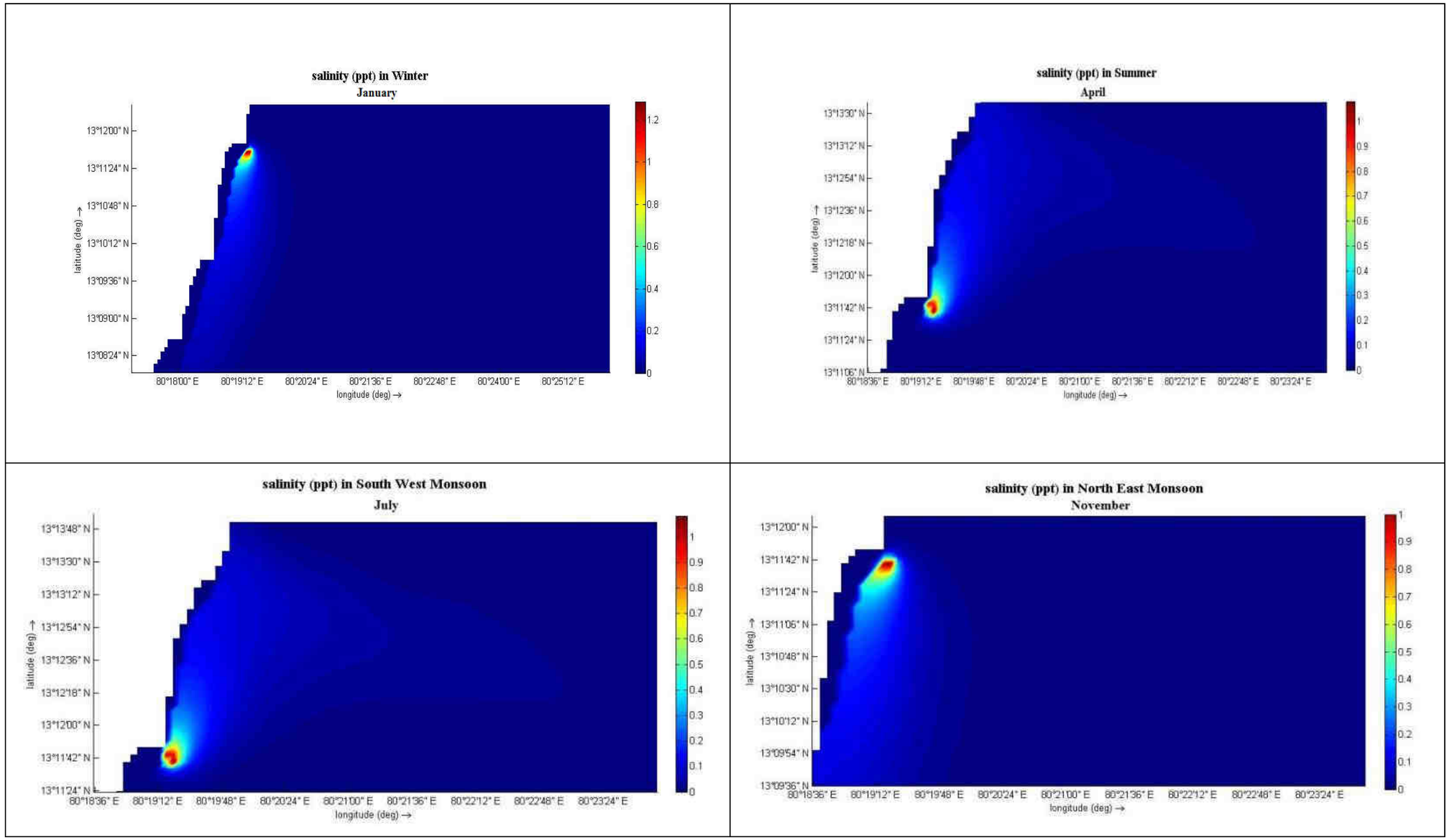
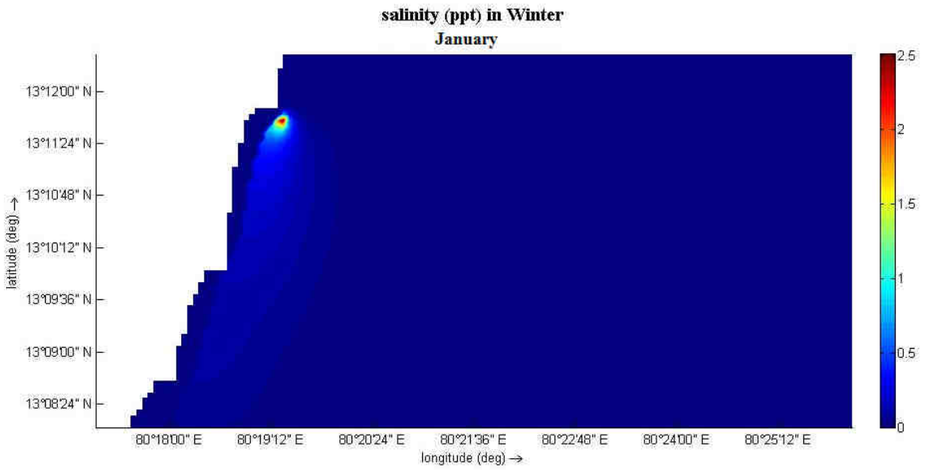
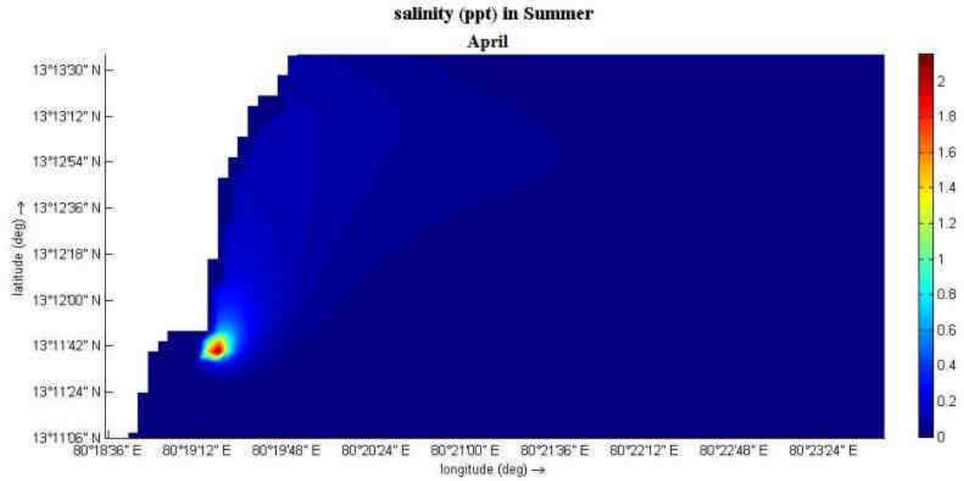
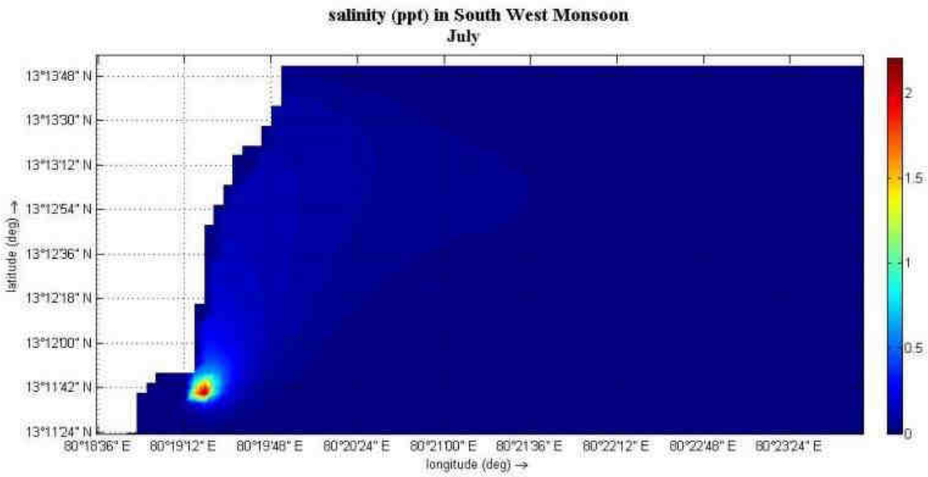


Figure 4-15shows the area plot of seasonal salinity dispersion during Spring-Flood. The distance of high salinity concentration falling within 0.5 ppt above ambient for winter, summer, South West monsoon and North East Monsoon from the outfall location of the power plant is about 632m, 498m, 482m, and 569m respectively.

Figure 4-16 Area Plot for seasonal salinity Dispersion during Spring-Ebb







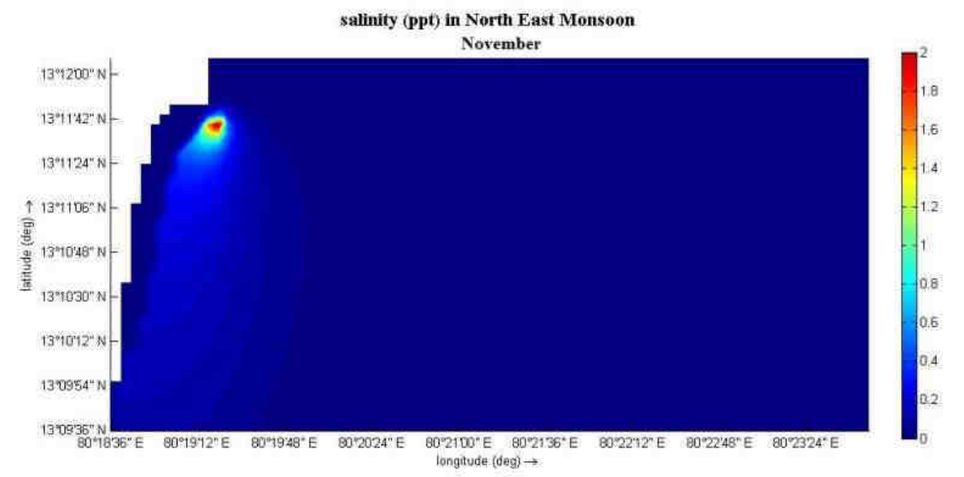
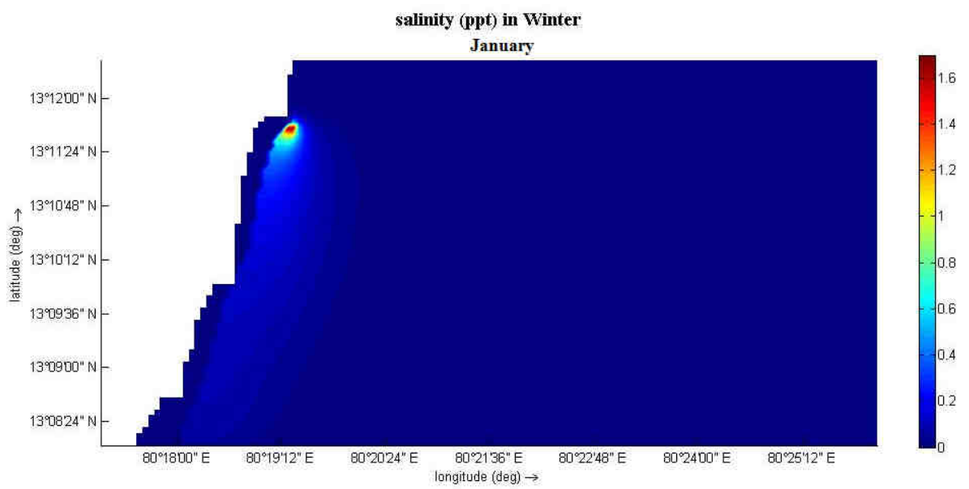
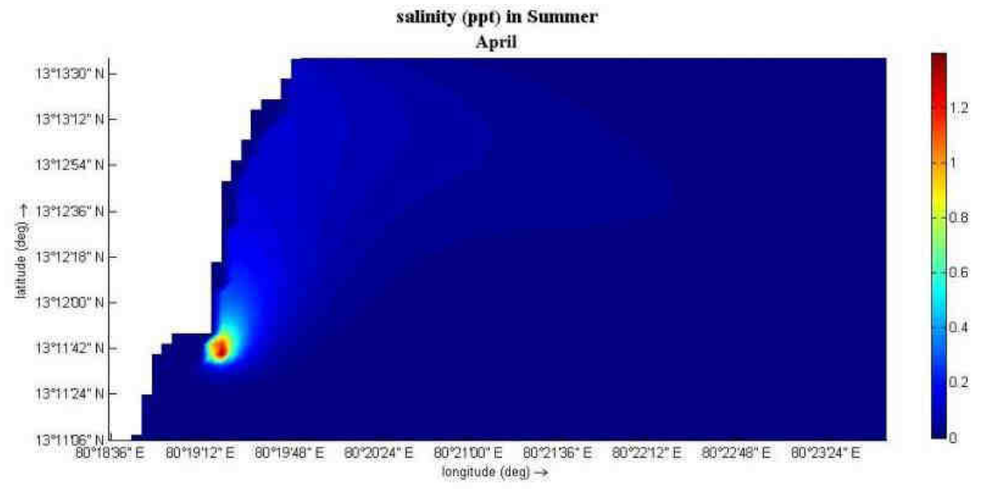
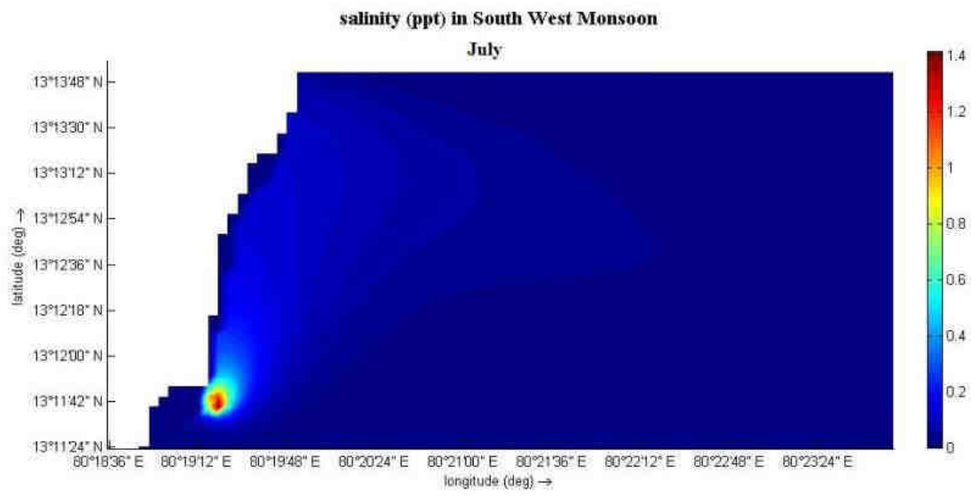


Figure 4-16shows the area plot of seasonal salinity dispersion during Spring-Ebb. The distance of high salinity concentration falling within 0.5 ppt above ambient for winter, summer, South West monsoon and North East Monsoon from the outfall location of the power plant is about 891m, 781m, 840m, and 790m respectively.

Figure 4-17 Area plot for Seasonal Salinity during Neap -Flood







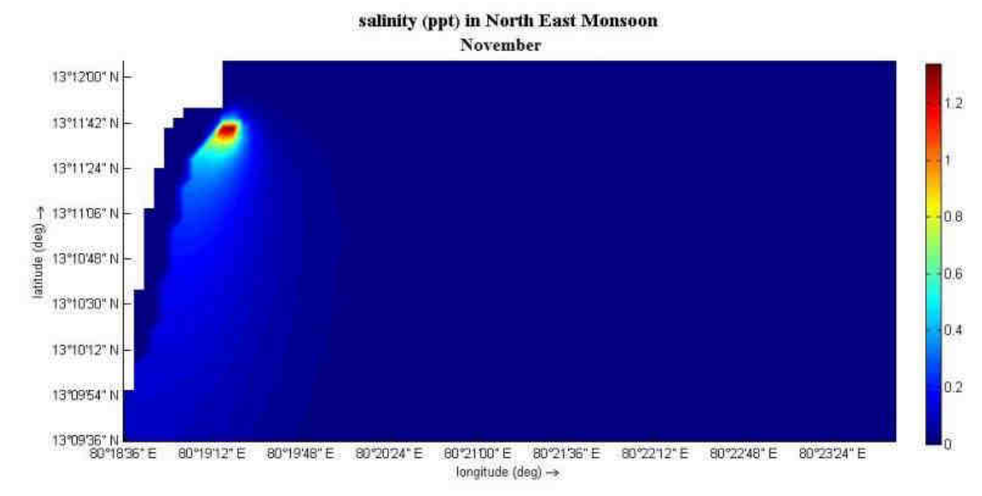
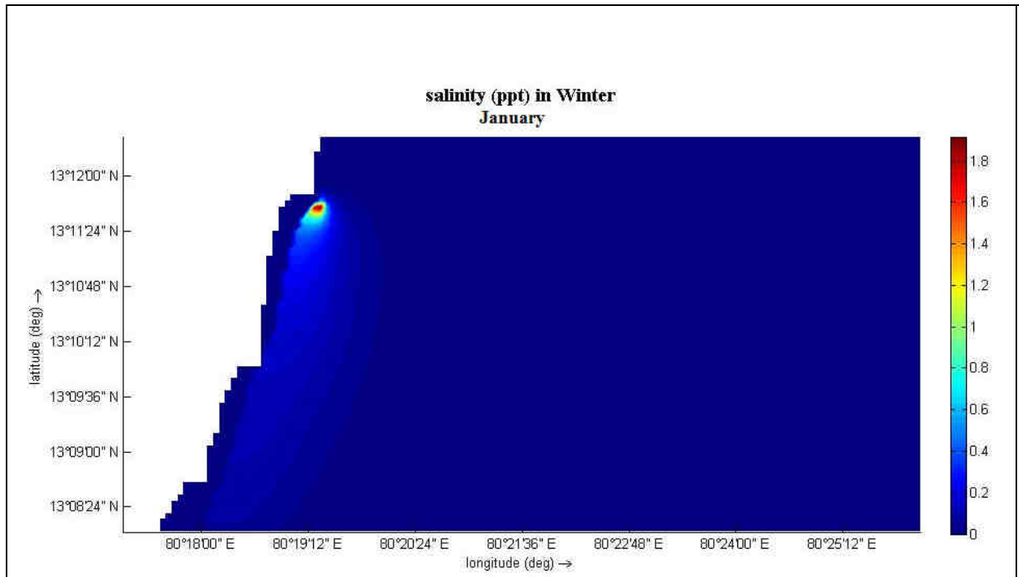
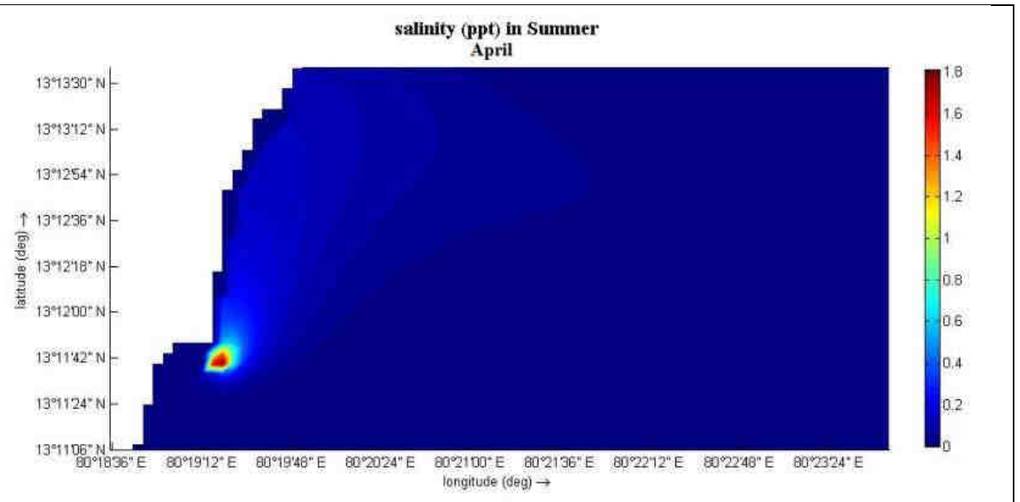
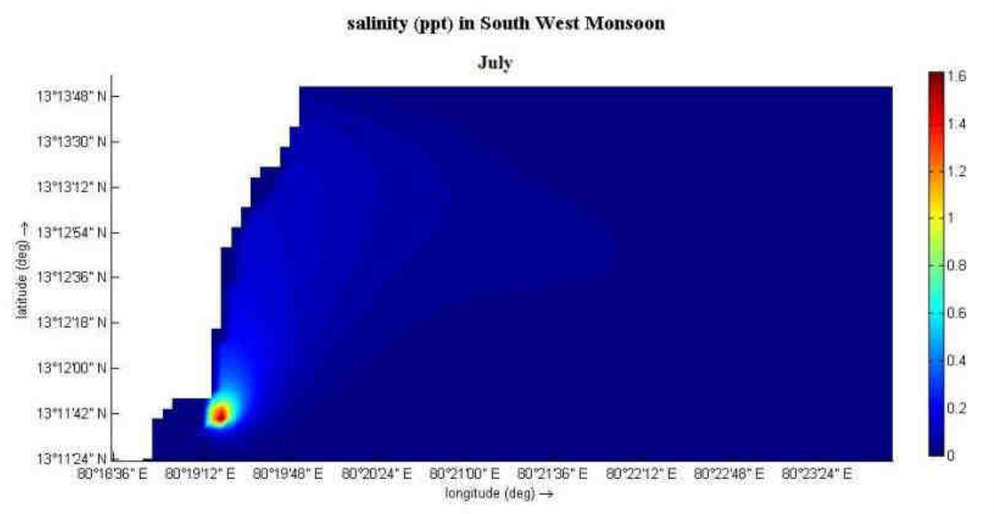


Figure 4-17shows the area plot of seasonal salinity dispersion during Neap-Flood. The distance of high salinity concentration falling within 0.5ppt above ambient for winter, summer, South West monsoon and North East Monsoon from the outfall location of the power plant is about 662m, 540m, 564m, and 616m respectively.

Figure 4-18 Area plot for seasonal Salinity Dispersion during Neap-Ebb







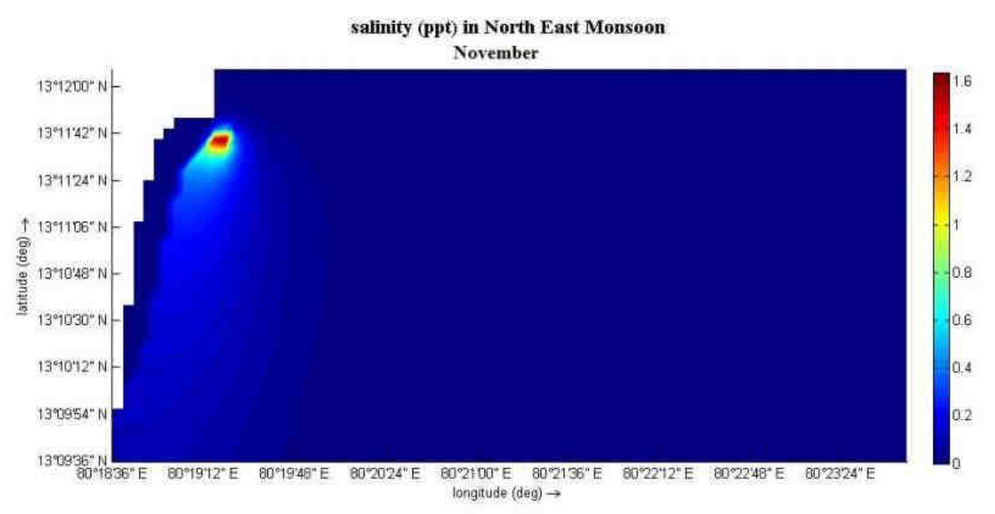


Figure 4-18shows the area plot of seasonal salinity dispersion during Neap-Ebb. The distance of high salinity concentration falling within 0.5ppt above ambient for winter, summer, South West monsoon and North East Monsoon from the outfall location of the power plant is about 735m, 614m, 740m, and 755m respectively.

4.2 Impacts of Outfall on Sea water Quality

The modelling studies for spatial distribution of temperature and salinity of the outfall from the power plant indicate no major increase in the concentration with respect to baseline value. However identifying and analyzing the possible impacts that may be caused due to the outfall on the marine environment shall aid in mitigating and neutralizing such impacts.

The discharge of coolant water into the sea will cause a thermal plume and increase the temperature of seawater. The dispersion of the plume shall vary based on the ocean currents and other parameters. Though the dilution factor of thermal outfall into seawater is high the concentration value at the point of outfall will be higher than the baseline values and will alter the sea water quality, making species sustainability difficult. Increase in temperature will lower the dissolved oxygen content of the receiving water and impact the marine species. Increased temperature changes the natural balance of sea water and directly affects the processes in water. Increased salinity concentration will increase the density of water affecting the sensitive benthic and plankton species. Higher salinity in seawater can benefit certain organisms such as shellfish but affect other species like, reduction in species growth survival at larval stage, shorter life expectancy, reduction in population density, breeding and reproductive activities.

To prevent the growth of organisms and waste build-up in the outfall pipeline anti-fouling agents will be applied; the interaction of thermal plant outfall along with these anti-fouling agents will affect the physic-chemical and biological quality of seawater, in turn affecting the species that inhabit the region. Chlorine is the major component in the anti-fouling agent and excess quantity of chlorine into the seawater will cause sweater toxicity and be harmful to the marine species. On analyzing the model results it can be concluded that no major variation can be observed the marine water quality with respect to temperature and salinity and the increase in baseline values due to coolant water outfall is very minimal and be neutralized hence, no major impacts shall be envisaged on the marine environment due to the proposed project activities.

4.3 Effects of Turbidity on Marine Ecosystems

Turbidity is an optical quality of water and describes how clear or transparent the water is. It describes the degree to which the water contains particles that cause cloudiness or muddiness

resulting in the disturbance of sunlight. Turbidity may be found in water bodies such as oceans, lakes and rivers. High turbidity may be caused by a high content of fine sediments or organic particles.The major source of turbidity is the phytoplankton.

According to the report by Aron Borok[10], turbidity affects the growth of macrophytes and eelgrass in lakes. Increased turbidity causes decrease benthic macrovertebrate abundance and diversity, as well as populations of zooplankton. Turbidity can affect these populations in 2 ways: 1) turbidity may reduce the primary production of phytoplankton thus affecting the primary consumers and 2) increased turbidity and suspended sediments may cause drift of macroinvertebrates due to clogging of benthic habitat. Turbidity also affects the behavioral effects of fish such as changes in territorial behaviour, avoidance of turbid water, increased blood sugar levels and change in visual effects of suspended sediment.

The suspension of fine sediments in the ocean waters may influence nutrient dynamics in estuaries, affect growth of primary producers and impair the performance of visual predators. The microphytobenthos is dependent on the natural turbidity and thus any change in that will affect this species. However, increased turbidity does not cause any significant effect on the productivity of micro-algae. Increased turbidity will cause a significant decrease in biomass and productivity of phytoplankton, zooplankton and filter-feeding benthos[11].

Light penetration in oceans is affected by the inorganic turbidity and thus decreasing the fraction of light absorbed by photosynthesizing organisms thereby reducing their density, growth rates and production of phytoplankton. The flagellates have greater motility and reduced sensitivity to flocculation. The phytoplankton density reduces when the algal cells sinks by adhering to clay particles in the turbid waters.

Turbid environment favours the young fish in terms of survival by reducing risk of predation by large predators. The feeding depends on the light as well as prey density. When there is high turbidity, the light is extinguished and the prey density could become important in influencing feeding success, growth and survival. The juveniles can consume the available

[10] Aron Borok (2014), Turbidity Technical Review, Water Quality standards published by Department of Enviornmental Quality, State of Oregon

[11] Essink, Karel(1999), Ecological effects of dumping of dredged sediments; options for management, Journal of coastal conservation 5: 69-80,1999

food in darkness and the prey concentration is maximum. Also, the juvenile fishes may be spatially separated from adult weakfish[12].

4.4 Effects of Salinity on Marine Ecosystems

Changes to salinity can play a significant role in the growth and size of aquatic life and the marine species disturbance. Changes in the salinity can play two opposite roles on the marine organisms' existence; it can be of benefit for some of these organisms such as shellfish and at the same time can have an adverse impact on other species.

The salinity observed in the project area ranges between 31 ppt to 33 ppt. The proposed outfall from the Thermal Power plant will be 5 ppt higher than the ambient salinity conditions. As per the modelling study, the salinity will get diluted to the ambient conditions within a radius of 300m. The impact on the receptors is mainly categorized into Plankton, Intertidal habitats, Fish and Fish larvae etc. the long-term average temperature increase assessed from modelling studies is 0.5° to 0.75°C above the ambient temperature at the outfall.

4.5 Effects of Temperature on Marine Ecosystems

Effect on plankton species have limited or less motility and their occurrence and distribution within a sea area is thus governed by external factors such as hydrodynamic regime, vertical mixing within the water column etc. As they do not have a selective avoidance mechanism of unfavourable conditions, they are susceptible to environmental changes both natural and anthropogenic, including the direct influence of thermal discharges.

There is a range of potential effects on planktonic communities that can result from increases in water temperature. Changes to the temperature regime of the water column in the receiving environment can have direct effects on planktonic species, as metabolic rates are dependent upon temperature.

Exposure to higher temperature in the order of 2° C usually leads to changes in the community structure. In the proposed project the temperature rise is 0.5 ° C to 0.75°C in a radius of 600m. So the effects resulting due to the temperature difference will be minimal.

[12] *Paul A. Grecay & Timothy E.Targett (1996), Effects of turbidity, light level and prey concentration on feeding of juvenile weakfish Cynoscion regalis, Marine ecology progress series, Vol. 131: 11-16,1996*

Further the modelling studies shows that the temperature gradient declines as it moves towards the seaward side. Hence no adverse impact is anticipated.

4.6 Effects of Antifouling Agent on Marine Ecosystems

There are potential operational issues caused by the growth or encrustation of marine organisms in pipes and inlet wells. Operationally, the colonization of marine organisms such as algae, bryozoans and molluscs within cooled water circuits could result in losses in thermal efficiency and reduced reliability of the system (including total shutdown).

To counteract settling and growth of marine organisms, cooled water circuits are typically dosed with chemicals (usually sodium hypochlorite). Such chemicals are known as antifoulants and they inhibit the growth of organisms within the circuit by creating unsuitable living conditions. A secondary consequence of this form of treatment is associated with the discharge of the treated seawater into the marine environment.

The concentration of chlorine in the inlet is 1ppm which is similar to that found in the cooling waters of power stations operating worldwide and is below the proposed power plant discharge limits. Concentrations of residual chlorine have been shown to diminish rapidly with time and distance from the discharge point(Mattice & Zittel, 1976).

The concentration in the outfall shall not exceed 0.5mg L-1 which is acceptable as per EPA guidelines. Consequentially, significant impacts to fisheries resources as a result of the discharge of chlorinated water are not expected to occur. As per literature review, it is observed that residual chlorine at a concentration of 0.5mg/L on the hatching of fish larvae was found to have no significant impact.

5 MARINE ENVIRONMENT MANAGEMENT PLAN

This chapter presents the tool for effective sustenance and management of the marine environment from any potential impacts that may affect the ambient condition of the surrounding environment – in this case the Ennore Thermal Power Station, Tamil Nadu. The effectiveness of Environment Management Plan (EMP) shall be assessed by developing a post project monitoring program (PPMP), which has been presented in Chapter 6. Upon successful implementation of EMP and by adopting good engineering and operational practices, the traces from the construction and operation phase of the ETPS will have minimal impact on the marine environment, which can otherwise be considered as insignificant. The following section describes EMP developed for construction and operation phase of the project.

5.1 Construction Phase

The construction phase involves the laying of pipelines for the intake of seawater and outlet of the used water into the sea. The management plan pertains to the ancillary infrastructure that are being constructed/developed in the coastal / marine environment, as part of the ETPS expansion.

5.1.1 Water Quality Management

The laying of the seawater intake pipeline, construction of intake terminal, and laying of outfall would foresee localized alteration of water quality due to disturbance to the sea bed. The intake and outfall pipeline would be laid below the seabed which involves digging of trenches. Considering the aforementioned and to reduce the effect on the water column the following recommendation are made.

1. Installation of silt screen shall be done to confine the suspended sediment to the project area.
2. Increased monitoring for turbidity to incorporate or re-orientate silt screens accordingly.
3. Decrease rate of dredging/excavation.
4. Select appropriate dredge method / technology for reduced impact of dredging on the surrounding environment.
5. Washing down of construction equipment is not permitted within 100m of the high water mark/high tide line

6. Monitoring sites shall be established to provide information on the sea water quality variation at the proposed Seawater Intake and Outfall Location

5.1.2 Fish and Marine Life Management

Fish management involves activities undertaken to protect and control fish and other marine species along the coastal stretch of Ennore. The stretch where he proposed intake and outfall pipelines are to be laid should be isolated for laying of pipelines. Any fish or other marine life that may be trapped within should be removed prior to the start of works. To perform that, an experienced professional need to be in place during the process of fish recovery from the construction site to avoid any loss of fish stock near the coast.

5.2 Operation Phase

The operation phase is the post development phase, once the installed supercritical thermal power unit has been put into operation. This phase would require intricate management of the marine environment due to the intake of seawater and outlet of the process water which would be of higher temperature as opposed to its intake temperature. The outlet of such water would collapse the biological diversity at the discharge point, for which necessary actions are to be taken.

5.2.1 Outfall Water Management

The water quality at the discharge point shall be analyzed for any change in the physicochemical as well as the biological parameters in the marine water. Besides the discharge point, the water quality shall be analyzed for the aforementioned parameters within the 5 km radius to assess for any effect on water quality due to the discharge of thermal/process water. Any change in the water quality observed shall be fixed by the ETPS in their process.

Accidental Oil Spill Management Plan

Though the proposed project is only for the intake and discharge of the seawater, there could be accidental oil spills in the marine environment due to the close proximity of the North Chennai Port. The following management measures are applicable in case of oil spill in the vicinity of the intake and the outfall structure:

- Notify the Indian Coast Guard in case of any oil spill noticed.

- The intake of water shall be suspended till oil spill is cleared as there is high chance of oil to be absorbed by the intake pipeline which would result in damage to the structures.
- The discharge of the water shall also be suspended since the discharge shall help in dispersion of the oil spill.

6 ENVIRONMENTAL MONITORING PLAN

An environmental monitoring programme is required to provide scientifically defensible information for determining the status of the environmental quality of the surrounding area of the intake and the outfall points of the Expansion project of ETPS and to ensure the outfall temperature is within the environmentally acceptable limit as per the Thermal Power Plant Standards. This will help to obtain an early warning of unacceptable environmental conditions so that control measures can be taken immediately. It also helps to determine in a timely fashion, changes in the local environmental quality.

Long term monitoring is proposed near the intake and outfall location especially to measure the temperature, salinity and biological parameters.

6.1 Water Quality Monitoring

The water quality monitoring programme consists of parameters monitoring prior to discharge, water quality monitoring near sea intake and outfall structure and nearby surface water.

Table 6-1 Water and Wastewater Monitoring Schedule- ETPS Expansion Unit

Waste Water Sources	Frequency of Analysis	Parameter of Examination
Boiler blow down	Monthly	Temperature suspended solids, oil & grease, dissolved solids, copper, iron etc.
Water treatment plant Effluent	Weekly	pH, suspended solids COD, BOD, dissolved solids
Ash Pond Effluent	Monthly	pH, suspended solids, oil & grease, dissolved solids, heavy metals like chromium, zinc, iron, manganese, aluminium, nickel etc.

The monitoring schedule for analysing the marine environmental quality parameters to be analyzed are shown in**Table 6-2.**

Table 6-2 Seawater Quality Monitoring Program- Construction Phase

Environmental Component to be monitored	Parameters to be monitored	Locations	Monitoring Frequency	Responsibility

Environmental Component to be monitored	Parameters to be monitored	Locations	Monitoring Frequency	Responsibility
Seawater Quality	Total Suspended solids, Total Dissolved Solids, Salinity, temperature, Chlorine, Heavy metals, BOD, Oil products, pH.	Seawater Intake and Discharge points	Every 15 days during the construction period	TANGEDCO
Sediment Quality	Trace metals, Nitrate-nitrogen, Phosphate-phosphorus.	Seawater Intake point, Discharge points, 100 m from the discharge point, creek	Every 15 days during the construction period	TANGEDCO
Marine biological environment	Phytoplankton, Zooplankton and Benthos	Seawater Intake point, Discharge points	Monthly	TANGEDCO
Marine Sediment	Benthic biomass and population	Seawater Intake point, Discharge points, creek	Monthly	TANGEDCO

Post Project Monitoring of Marine Environment

Post project monitoring for marine environment should be carried out in order to ensure that the environmental quality is maintained. Specially trained staff should be employed to undertake the monitoring work in a control laboratory of the plant or this work could be assigned to any research Institute/NABL accredited Laboratory having expertise in collection and analysis of sea water and sediment samples in offshore and intertidal region.

Table 6-3 Seawater Quality Monitoring Program- Operation Phase

Environmental Component to be monitored	Parameters to be monitored	Locations	Monitoring Frequency	Responsibility

Environmental Component to be monitored	Parameters to be monitored	Locations	Monitoring Frequency	Responsibility
Seawater Quality	Total Suspended solids, Total Dissolved Solids, Salinity, temperature, Chlorine, Heavy metals, BOD, DO, Oil products, pH, Conductivity and Total Residual Chlorine. (Temperature increase at discharge should be within 5°C).	Seawater Intake point, Discharge points, 100 m from the discharge point, creek	Monthly	TANGEDCO
Sediment Quality	Trace metals, Nitrate-nitrogen, Phosphate-phosphorus.	Seawater Intake point, Discharge points, 100 m from the discharge point, creek	Monthly	TANGEDCO
Marine biological environment	Phytoplankton, Zooplankton and Benthos	Seawater Intake point, Discharge points, 100 m from the discharge point, creek	Monthly	TANGEDCO
Marine Ecology	Marine organisms trapped in the pipe intake and outfall structure	Intake and outfall structure	Once in 15 days	TANGEDCO
Marine Sediment	Benthic biomass and population	Seawater Intake point, Discharge points, 100 m from the discharge point, creek	Monthly	TANGEDCO

Environmental Component to be monitored	Parameters to be monitored	Locations	Monitoring Frequency	Responsibility
Intertidal Coastal environment	Beach profile, Intertidal habitats	Intertidal region near to the intake and outfall points and along the pipeline route	Annually	TANGEDCO
Shoreline	Erosion and Accretion	2 km on either side of the intake and outfall points	Annually	TANGEDCO
Physical Process and Seafloor	Currents, waves, Tides and Bathymetry	Along the pipeline route of intake and outfall	Annually	TANGEDCO

7 SUMMARY AND CONCLUSION

Ennore Thermal Power Station (ETPS)is a coal fired power station located in Ernavur village, Thiruvottiyur Taluk in Tiruvallur district, Tamil Nadu, India. ETPS is owned and operated by the Tamil Nadu Generation and Distribution Corporation (TANGEDCO), a subsidiary of the Tamil Nadu Electricity Board (TNEB).The existing ETPS was of 450 MW capacity which was in operation from 1975. The facility has been dismantled on 31st March 2019 and is proposed to be replaced with a 1x660 MW unit within the same facility. It has been also proposed that to expand the ETPS by an additional 1x660 MW super-critical technology.

The proposal for expansion would improve the capacity of the power generation by ETPS and the environmental clearance for the expansion of ETPS has been obtained in the year 2009. The validity of the clearance was upto 2nd June 2019. But the works relating to the construction of the facility has not been completed. Since the maximum validity of the clearance has been obtained. A fresh proposal has been submitted by TANGEDCO and ToR has been accorded by MoEF&CC for which the marine EIA study has been entrusted to Cholamandalam MS Risk Services Ltd, Chennai.

The proposed expansion facility will use super-critical technology. The water requirement will be met by Bay of Bengal. The outfall and the intake locations have been located as per the detailed study by NIO, Goa. The intake pipeline and the outfall pipeline has been provided at a distance of 650m and 250m respectively from the shore. The intake and the outfall are provided at different directions from each other to avoid mixing of water. The total quantity of intake for the Replacement unit and the Expansion unit is 25000 m^3/hr and the total quantity of discharge is 16000 m^3/hr.

The baseline monitoring has been carried out for the proposed facility for one season. The water and sediment samples have been collected from the offshore locations (inclusive of intake and outfall) and the creek. The creek samples have been analysed since the coal conveyor belt is proposed across the creek. The water and sediment samples have been analysed for the physio-chemical parameters and biological parameters. The results have shown a few traces of contamination in the creek. The offshore samples have shown diversified phytoplankton, zooplankton and benthos. Since the nature of the ocean is dynamic, the pollutants, if present, shall get dissipated in no time.

The thermal and salinity dispersion modelling has been conducted for a combined intake and outfall for the replacement unit as well as expansion unit which accounts to 2x660 MW capacity. The temperature and salinity at the intake and the outfall locations have been considered for the modelling study. The outcome has revealed that the temperature and salinity at the discharge location has been dissipated to a distance within 1 km for spring and neap tides for the ebb and flood conditions irrespective of the seasons.

The impacts of the temperature and salinity dispersion on the ecology and the marine environment has been analysed. Since the temperature and salinity at the discharge point diffuses and disperses within a short span of time, there will not be major impacts on the marine environment as well as ecology. Furthermore, the effect of anti-fouling agents on the marine ecosystem has also been discussed. It is mentioned that the levels of chlorine in discharge has to be limited so that it will not affect the marine ecology and environment.

The environmental management plan has been discussed to mitigate the impacts at the construction and the operation phase of the project. The management of the water quality in the marine environment is addressed with respect to the discharge characteristics of the outfall water from the Thermal Power Plant. The precautionary measures taken for the laying of pipeline and the measures to manage the ecology in the marine environment during the construction and the operation phase has been addressed in the respective sections.

Environmental Monitoring Program is provided to ensure that the surrounding environment is stable and not affected by the proposed project. It is also helpful to monitor and maintain the temperature of discharge within the standards set for Thermal Power Plants. Similar to the Environment Management Plan, Environmental monitoring plan is also devised for the construction and the operation phases of the project.

So, the overall outcome of the study reveals that the impacts of thermal and salinity dispersion of the discharge waters on the marine environment is negligible. Since the dispersion is fast and does not travel longer distances to match the ambient conditions, the proposed project is acceptable.