ASSESSING THE IMPACTS OF OIL SPILLAGE FROM SHIPS ON COASTAL ENVIRONMENT OF BANGLADESH: MEANS FOR RESPONSE AND MITIGATION

A Dissertation for the Degree of Master in Disaster Management

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Abstract

Commonly we hear about the biggest oil spills but oil spills occur every day. Some spills are unintentional while others are deliberate illegal discharges of bilge oil ship's waste.

As long as society depends on oil and petroleum products, spills are a substantial risk. Understanding environmental impacts along contingency planning is needed to mitigate the affects of oil spills.

O'I spilled at sea has numerous environmental impacts affecting everything from seabirds to sea life to life on land.

The coast of Bangladesh stretching to about 710 km where approximately 12%) of the country's 150 million population live is known as a zone of multiple vulnerabilities as well as opportunities. It is prone to several natural disasters such as cyclones, Storm surges, floods and river erosion. In combination with the other natural hazards, man- made hazards in various forms like land based pollution from agricultural chemical, industrial residues, farm effluents, solid waste, sewage disposal and top of all. pollution from ships due to both operational and accidental oil spillage, pose the coasts of- Bangladesh with greater and larger threats of devastation and inexpressible damage to lives, properties, livestock, infrastructures, life support chain and environment.

The fate and behaviour of' oil on shorelines is influenced by many factors. Some of which relate to the type of oil, some to characteristics of the shoreline and others to conditions when the oil is deposited on the shoreline such as weather and waves. For example, an oil slick could be carried by surface currents or winds to areas where it causes the greatest damage to wildlife habitat. On the other hand, a slick could be carried out to the deep sea where it disperses naturally and has lesser direct effect on the environment.

Contingency planning is an important step in ensuring of lective response to oil Spills-Response teams include operations , science and communications personnel. Action planning includes stopping the flow of oil, containing the oil, and cleaning it up.

About five thousand ships including a number of oil tankers come and operate in our ports every year. There are several thousand other mechanized trawlers and coastal vessels and boats that spill oil. Sea is also polluted severely polluted by oil spill because of accidents of ships. The authority fails to check pollution as they do not have provision for receiving or collecting oil related wastes and vessels facing emergency situation during oil spillage. Even our Port Authorities have no laboratory nor required surveillance facilities to check the pollution. Foreign and local ships find our ports and its outer anchorages a safe dumping heaven for disposal of wastes, taking advantage of poor laws and their lax implementation due to poor logistic support. The authority fails to take action against the ships as they lice the scenes very quickly after dumping waste in our territorial waters. Besides, ship breaking industry is located in Chittagong and incidents like dumping of wastes into the sea from ships also happening.

Coast of Bangladesh, the life line of the land opens up the opportunity of development and prosperity for the country. The funnel shaped coast lacing Bay of Bengal provides Bangladesh in one hand one of the best locations geographically for sale recluse of ports and resorts and habitation and similarly on the other hand poses a serious threat of hazards due to oil spillage from ships and their accidents.

The coast of Bangladesh has already experienced a number of oil tanker accidents but being in small scale has failed to draw any public concerned or attention. With rise in frequency of transportation of crude oil in particular has prompted even larger tankers to come to Bangladesh Coast posing possibility of accidents due to grounding, collision and explosion spilling huge amount of crude oil to the sea sufficient to cause devastation to lives, properties and environment.

Where the oil spillage from ships has already drawn great concerns to developed countries formulating and implementation of a series of international conventions to control and mitigate the risk, it is ironical that the hazard of oil spillage from ships have not been able to draw any meaningful public concern for taking concerted efforts of mitigation

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Contingency planning is an important step in ensuring effective response to oil spills. Response teams include operations. science and communications personnel. Action planning includes stopping the flow of oil, containing the oil, and cleaning it up.

This dissertation study work is an effort to create understanding of the whole issue in the overall context of Bangladesh and create awareness to prepare the country being a maritime nation for possible and appropriate mitigation and response measures.

Acknowledgement

Impact of Oil Spillage and its consequence may cause disaster to our coastal environment to extent of havoc and devastation not known to most of us. Creating awareness among the concerned in particular and the mass in general is a demand of the time. To this end, the efforts of BRAC University introducing the course of Disaster Management and pioneering the education deserve special thanks enabling the country being the most disaster prone in the world to have professionals to care and handle and contribute in the field. Sincere thanks also go to various government and non government officials without whose support and cooperation. the study would not have been possible. Would also like to thank to Canadian International Agency (CIDA) and Comprehensive Disaster Management Programme (CDMP) fbr extending their assistance in various forms including continued financial assistance to this cause.

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Acronyms

NEBA	Net Environmental Benefit Analysis
PDO - ICLMP	Programme Development Office for Integrated Coastal Zone Management Plan
ESCAP	Economic and Social Commission for Asia and the Pacific of-the UN
UN	United Nations
ADB	Asian Development Bank
SRDI	Southern **Rural** Development Initiative
MoWR	Ministry of Water Resources
UNDP	United Nations Development Programme
CPA	Chittagong Port Authority
MPA	Mongla Port Authority
IMDG	**International** Maritime Dangerous Goods
ASEAN	Association of South-East Asian Nations
FAO	Food and Agriculture Organisation of the UN
RAPA	Risk Assessment & Policy Association
UNEP	United Nations Environment Programme
GI:SAMP	Joint Group of Experts on the Scientific Aspects of Marine Environment Protection
WRI	World **Resource** Institute
DOE	Directorate of Environment
ITOPF	**International** Tanker Owners Pollution Federation
DOS	Directorate of Shipping
ISO	**International** Organization for Standardization
DoF	Department of Forestry
MoF	Ministry of Environment
BPC	Bangladesh Petroleum Corporation
DWT	Deadweight Tonne
IMO	International maritime Organization
OPRC	Oil Pollution Preparedness. Response and Co-operation
ECA	Environmental Conservation Act
EC R	Environmental Conservation Rules

EIA	Environmental I**mpact** Assessment
SACEP	South Asia Co-operative Environment Programme
SARSP	South **Asian Regional** Seas Programme
BIW'FA	**Bangladesh Inland Water** 'l'ransport Authority
MARPOL	**Marine Pollution** Convention
CPA	Chittagong Port Authority
MPA	Mongla Port Authority

Chapter 1: Introduction

1.1 Background

The coast of Bangladesh is known as a zone of multiple vulnerabilities as well as opportunities. It is prone to several natural disasters, such as cyclones, storm surges, floods and river erosion. In combination with the other natural hazards, man-made hazards in various forms like land based pollution from agricultural chemical, industrial residues. farm effluents, solid waste, sewage disposal and top of all, pollution from ships due to both operational and accidental oil spillage. pose the coasts of' Bangladesh with greater and larger threats of devastation and inexpressible damage to lives, properties, livestock, infrastructures, life support chain and environment.

About five thousand ships including a number of oil tankers come and operate in our ports every year. There are several thousand other mechanized trawlers and coastal vessels and boats that spill oil. Sea is also polluted severely polluted by oil spill because of accidents of ships. The authority fails to check pollution as they do not have provision for receiving or collecting oil related wastes and vessels lacing emergency situation during oil spillage. Even our Port Authorities have no lahoratory nor required surveillance facilities to check the pollution. Foreign and local ships find our ports and its' outer anchorages a safe dumping heaven for disposal of wastes. taking advantage of poor laws and their lax implementation due to poor logistic support. H IC authority fails to take action against the ships as they flee the scenes very quickly after dumping waste in our territorial waters. Besides, ship breaking industry is located in Chittagong and incidents like dumping of wastes into the sea from ships also happening.

Coast of Bangladesh, the life line of the land opens up the opportunity of development and prosperity for the country. The funnel shaped coast facing Bay of Bengal provides Bangladesh in one hand one of the best locations geographically for safe refuge of ports and resorts and habitation and similarly on the other hand poses a serious threat of hazards due to oil spillage from ships and their accidents.

The coast of Bangladesh has already experienced a number of oil tanker accidents but being in small scale has failed to draw any public concerned or attention. With rise in frequency of transportation of crude oil in particular has prompted even larger tankers to come to Bangladesh Coast posing possibility of accidents due to grounding, collision and explosion spilling huge amount of crude oil to the sea sufficient to cause devastation to lives, properties and environment.

Where the oil spillage from ships has already drawn great concerns to developed countries formulating and implementation of a series of international conventions to control and mitigate the risk, it is ironical that the hazard of oil spillage from ships have not been able to draw any meaningful public concern for taking concerted efforts of mitigation.

It **has become a normal and almost a perceived** way of **life that unless and until there is any catastrophe and huge loss lives, no one raises any** voice of concern **of the threats and** risk of **hazards and even so, no appropriate measure is taken if** ' no foreign **fund is made available. Issue of oil spillage from ships though have** drawn **some attention of related agencies of the country due to compulsion from ratification** of related **international conventions**, **but effective and comprehensive mitigation plan and measures** arc still far **from reality to address the issue adequately in the Disaster Management** perspective.

The matter being a demand of the time, conduction of' a systematic and comprehensive study under the framework of Disaster Management has become imperative before it goes too late and better address the whole issue from the national perspective. Keeping this in view, as a prerequisite of Post Graduate Program in Disaster Management, the proposed study work from academic perspective will enable to examine associated threats and risks out of the impacts of hazards oil spillage from ships and find out and suggest available mitigation alternatives as deem fit and appropriate for the country in consideration of its resources and limitations and saving valuable lives and properties and environment from disaster.

1.2 Statement of the Problem

The occurrence of oil spill incidents in different parts of the world has heightened worldwide concern about the serious environmental consequences. Ships used for transporting the oil account for major oil spillages. In Bangladesh. there are two major international ports - Chittagong and Mongla. Chittagong Port has the country's lone oil refinery with approx. 5.0 million metric tons oil imported annually fro Persian Gulf ports, including finished oil products. All finished products both refined in LRL (Eastern Refinery Ltd.) and imported are distributed to various points in Bangladesh through SRF (Sundarbans Reserved Forest) and Mongla Port from Chittagong Port. Mongla Port has lower direct oil spill risks than Chittagong Port owing to the lower traffic volume and absence of any oil refinery. Mongla Port is only 3 kilometers north of the Sundarbans Reserved Forest, which has been recently declared a World I leritage Site, Mongla Port is reached mainly by a 100 kilometer long navigational channel through the Pussur River System, which runs through the SRF. The throughput of this is expected to increase considerably making the need for environmental controls, monitoring, and enforcement more critically in the days to come.

Chittagong is the principal sea port of Bangladesh. Port operational parameter is extending due to **nation**'s economic growth and increased international importance. No doubt in Bangladesh, petroleum demand is rapidly increasing, and this trend will continue with economic growth. Importation of crude oil its refinement and movement of petroleum products by waterways and their storage in tanks at different oil depots appear to be potential oil spill sources. And top of this, risk of direct oil spill from ships due to accident involved in the transportation process have put the whole coastal belt including the coral island at St Martin in south **east region** and the Sundarbans in south west region of the country into real vulnerable strand.

It is praiseworthy to mention that the issues of' many other naturals hazards and its' possible impacts have been able to draw attention of the nation and media but hazards and impact of the oil spillage from ships on the coastal environment as whole have failed to raise necessary concern of the authority and media so that the nation is made prepared to face any impact of the hazard. It is therefore, he considered as the main intention of this study work to identify the risks involved, find out responsible factors causing disaster and recommend appropriate mitigation options for the country. Absence which losses and miseries will know no bound.

1.3 Objectives

The broad line objective of this study will be to carryout a systematic study of records to ascertain and identify potential hazards and impacts due to oil spillage from ships on the coastal environment of Bangladesh, sector wise and area specific.

The study **will cover the scenario of other countries Ile on the coast** of Bay of **Bengal and knowledge sharing necessity.**

The Study will discuss all related factors that are directly and indirectly influence the disaster of spillage of oil from ships.

The study will highlight experiences of developed countries to address the issue in the context of available technology and International Conventions and Regulations.

The study will explore viable measures of mitigation that deem fit for Bangladesh under constraints and limitations of resources. And to this end the study will follow a framework to identify the parties, agencies and authorities responsible to censure and ensure safety to vulnerable group of population, sectors and environment as a whole.

The Focus of the objectives of the study will be to ascertain mainly the following:

- Identify potential of hazards and impacts involved in oil spillage from ships
- Vulnerability of the coastal environment involved
- Understanding the underlying factors associated with the risk and vulnerabilities of the community.

- Understanding the underlying gravity of impact at different levels of' social life, livelihood and their preparedness and adaptive capacity.
- Factors responsible to cause spillage.
- General Risk Assessment using available tools-models to ascertain potential hazards due to oil spillage from ships and take countermeasures for mitigation and preparedness.
- Identify authorities and agencies responsible for the job of mitigation.

1.4 Methodology of the Study

A broad line methodology was used to understand implications and impacts of oil spillage related hazards, understand position of Bangladesh in the context of geographical location, intensity of oil transportation in the region**, transportation of petroleum products through the inland waterways**, **socio-econornical status to help to Frame guide lines for planning at national level to prevent, mitigate and prepare to face any impact due to oil spillage from ships out of causes either operational or accidental**. **Records available with Chittagong Port Authority. Department of Shipping and Department of Environmental Science of Chittagong University have been consulted and records available in their libraries have been reviewed and consulted with concerned officials and experts to assess hazards and vulnerability aspects and summarize covering** following **broad areas. Processed data have been presented in tables and graphs supported by maps and consulted with officials of relevant agencies and authorities to increase credibility of the study work for acceptance:**

1. Hazards in the context of geographical location
2. Sectors involved
3. Vulnerability and Capacity of the Community
4. Strength of resiliency
5. Adaptability
6. Socio economic condition

7. Perception and assumption of the affected community towards such hazards and mode of approaches
8. Impact on environment
9. Carryout Risk Assessment using Mathematical Model as tools considering:
   - Models in use in developed countries
   - Procedures and modus operandi of Models
   - Comparison of contemporary models
   - Case study in the context of coastal belt of Bangladesh
   - Recommend suitable model for use in the case of Bangladesh Coastal Zone and neighboring countries of the Bay of Bengal
10. Effectiveness and usefulness of response and relief and distribution
11. Effectiveness of various measures taken as responses, recovery and rehabilitation.

1.5 Scope and limitations of the study

1. Though limited but some information found available with various govt. agencies like, Department of Shipping, Port Authorities. Bangladesh and Chittagong University but lack of continuity of maintaining the records and review and follow up, have made the Study to depend on the records of studies carried out from time to time in other affected counties suffered from oil spillage related accidents and disasters.

2. Since no major oil spillage except few minor incidents occurred in the coast of Bangladesh, availability of detail records may not be possible but literature review will help to ascertain the gravity of risk of the hazard.

3. Time factor and budgetary constraints limits the extent of such study under academic pursue and without sponsorship.

4. Developed countries suffered from environmental damages due to oil spillage have put in place different approaches for the assessment of risks using models.

Literature review of reports and records have helped to prepare this Study work for the benefit of the country in need to follow similar approaches for mitigation preparedness against accidents of oil spillage in marine environment.

Chapter 2: Accidental Oil Spillage and Its Source

2.1 Hazards of Oil Spillage from Ships

An oil spill is the release of a liquid petroleum hydrocarbon into the environment due to human activity, and is a form of pollution. The term often relcrs to marine oil spills, where oil is released into the ocean or coastal waters. The oil may be a variety of materials, including crude oil, refined petroleum products (such as gasoline or diesel fuel) or by-products, ships' bunkers, oily refuse or oil mixed in waste. Spills take months or even years to clean up.

Oil is also released into the environment from natural geologic seeps on the sea floor. Most human-made oil pollution comes from land-based activity. but public attention and regulation has tended to focus most sharply on seagoing oil tankers clue to its catastrophic impact and consequences to environment and echo system and socio-economic development of the affected area.

Typically Marine pollution is more familiar in this part of world due to industrialization and other manmade activities. Type and speed of such land based pollution have more severe and direct impacts on inland waterways and sources than on the waters of the coastal area. However, impact of oil spillage liom ships due to accident (collision, grounding) in coastal belts poses much greater threat and impacts of damages to environment, echo system and socio economic activities of the affected area. If fact it is little known to our society about the hazards and its devastating consequences of accidental oil spillage from ships since fortunately no oil spillage of high magnitude have yet occurred in Bangladesh Waters except few minor incidents. As therefore, the purpose and intention of this study is to create awareness through examples of incidents of oil spillage and its consequences and impacts of damages so as to enable the country to well understand the vulnerability ofthe hazard and impacts to prepare and take risk reduction measures and preparedness.

Despite limitation of the length and scope of this paper, it would not he **exaggeration if few definitions of important terms are inserted in this chapter for better understanding and clarification.**

2.2 Definitions

Territorial waters, **or a territorial** sea: as defined by the 1982 United Nations Convention on the Law of the Sea, is a belt of coastal waters extending at most twelve nautical miles from the baseline (usually the mean low-water mark) ofa coastal state. The territorial sea is regarded as the sovereign territory of the AMC. although foreign ships (both military and civilian) are allowed innocent passage through it. this sovereignty also extends to the airspace over and seabed below.

The term "territorial **waters" is also sometimes** used informally to describe any area of water over which **a state has jurisdiction**, including **also internal** waters, the **contiguous zone, the exclusive economic zone** and potentially the continental shelf.

Petroleum - Crude Oil: The proportion of hydrocarbons in the mixture is highly variable and ranges from as much as 97% by weight in the lighter oils to as little as 50% in the heavier oils depending on contents of sludge and other non petroleum foreign particles.

The hydrocarbons in crude oil are mostly alkanes, cycloalkanes and various aromatic hydrocarbons while the other organic compounds contain nitrogen, oxygen and sulfur, and trace amounts of metals such as iron, nickel, copper and vanadium.

Crude oil varies greatly in appearance depending on its composition. It is usually black or dark brown (although it may be yellowish or even greenish).

Marine pollution: Major pollution of coastal waters occurs mainly from industrial discharge. municipal wastes, sewage and agricultural run-off. While Oil spill arises both from operational and accidental sources. Directly ship related operational sources are loading/discharging, bunkering and other routine operations like deballasting and debilging. Accidental sources are oil tank rupture, ship collision, grounding and hull failure. Other oil spill sources are from ship breaking operations.

2.3 Role of Ships and Tankers as Carrier of Oil

An oil tanker, also known **as a petroleum tanker**, is a ship designed for the bulk transport of oil. There are two basic types of oil tankers: the crude tanker and the **product tanker**. Crude tankers move large quantities of unrefined crude oil from its point of extraction to refineries. Product tankers. generally much smaller, are designed to move petrochemicals from refineries to points near consuming markets.

Oil tankers are often classified by their size as well as their occupation. The size classes range from inland or coastal tankers of a few thousand metric tons of' deadweight (DWT) to the mammoth supertankers of 550.000 I)W'I'_ Tankers move approximately 2 billion metric tons of oil every year. Second only to pipelines in terms of efficiency, the average cost of oil transport by tanker amounts to only two or three United States cents per gallon.

The tanker fleet includes some of the world's biggest **mechanically** propelled moving **objects, but the tern "tanker" covers** a wide variety of dill Crent types and sizes of **ships designed to carry liquids or gases** in bulk. Biggest **of all are** the Ultra Large **Crude Carriers**, **a handful of which are able to carry half a pillion tons of crude oil, although a more normal size range** is the Very Large Crude Carrier of between **250,000 and 300,000 tons capacity.**

There is also a sizeable fleet of around 140,000 tons, a class of ship which is able to pass laden through the Suez Canal, and serve a range of ports which the bigger ships could not enter. Crude carriers typically carry large cargoes of crude oil from the oil producing countries to the refineries. Arabian Gulf to Singapore or Japan, or North Europe is typical trade routes.

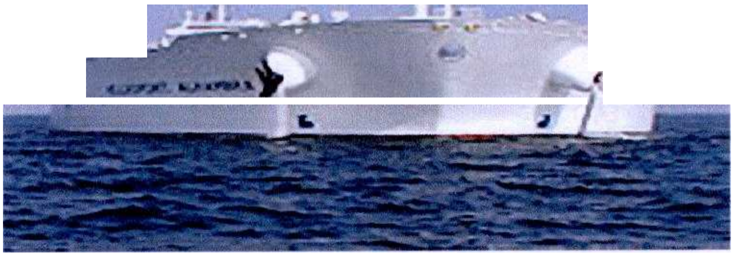
Product tankers are smaller vessels, of up to around 80.000 tons. ^0hich carry the many petroleum products of the refineries, clean white oil cargoes like gasoline or black oils like heavy fuel oil or diesel. These vessels begin the distributive process, moving from the refineries to the tank farms in the consuming countries, from where the oil cargoes are fed by road, rail, pipeline and coastal tankers and inland tank barges to power stations, and depots close to where the products are used.

The tanker fleet is a highly adaptable, responsive floating pipeline v'. hich is capable of' adjusting to considerable fluctuations in demand, as cold weather bites or industrial capacity increases. Ships can be switched to add or reduce capacity, or take advantage of price fluctuations, almost at a moment's notice. Oil being a traded commodity, the adaptability of tankers is highly important in this respect.
'tankers are enormously strong vessels, built with a honeycomb construction, a modern crude carrier typically having fifteen cargo tanks protected by a double hull structure around the sides and bottom, in which sea water ballast can he carried for the empty voyage after the oil cargo has been delivered. On such modern double hulled tankers, the oil and ballast remain separate, which greatly reduces the risk of pollution.

A tanker will normally be loaded by shore equipment, but will use her own powerful pumps to empty herself at the discharge ports. Crude oil comes in many forms, ranging from those that are light and free running, to heavy and waxy crude which require heating so they can be pumped freely. Most hydrocarbons are toxic and flammable and it is modern safety practice to keep the tanks tilled with a blanket of inert gas.

Specialist tankers include vessels which are configured to carry as many as fifty different grades of chemicals and oils, each with their own separate pumping systems and capable of coping with cargoes that need to shipped hot, cold or under a blanket of nitrogen. There are ships built of stainless steel for the carriage of acids, others with sophisticated coatings for the carriage of edible oils andwinc. Gas tankers carry LPG and Methane.

2.4 Contemporary Architectural and Structural Design of Tankers



***Source: The International Tankers Owners Pollution Federation Limited** (HOPI-)*

Oil tankers generally have from 8 to 12 tanks. Each tank is split into two or three Independent compartments by fore-and-aft bulkheads. The tanks are numbered with tank one being the forward most. Individual compartments are referred to by the tank number and the athwart ships position, such as "one port", "three starboard", or "six center."

A cofferdam is a small space left open between two bulkheads, to give protection from heat, fire, or collision. Tankers generally have cofferdams forward and aft of the cargo tanks, and sometimes between individual tanks. A pump room houses all the pumps connected to a tanker's cargo lines.U Some larger tankers have two pump rooms. A pump room generally spans the total breadth of the ship.

Ships' Hull Design:

tt ttt ttt ttt
Single Bottom

Double Bottom

1. if1
Double Hull

Source: The International Tankers Owners Pollution Federation Limited (ITOPF)

Single hull, Double bottom, and Double hull ship cross sections. Lines in green are watertight; structure in black is not watertight

A major component of tanker architecture is the design of the hull or outer structure. A tanker with a single outer shell between the product and the ocean is said to be *single-hulled.* Most new tankers are *double-hulled,* with an extra space between the hull and the storage tanks. Hybrid designs such *as double-bottom* and *double-sided* combine aspects of single and double-hull designs. All single-hulled tankers around the world will be phased out by 2026, in accordance with the International

Convention for the Prevention of Pollution from Ships, 1973 (MAKPOI ,). The United Nations has decided to phase out single hull oil tankers by 2010.

2.5 Oil Spillage and Pollution

Oil spills have devastating effects on the environment. Crude oil contains polycyclic aromatic hydrocarbons (PAHs) which are very difficult to clean up. and last for years in the sediment and marine environment. Marine species constantly exposed to PAIN can exhibit developmental problems, susceptibility to disease, and abnormal reproductive cycles.

By the sheer amount of oil carried, modern oil tankers must be considered a threat to the environment. As discussed, a VLCC tanker can carry 2 million barrels (320,000 m) of crude oil, or 62,000,000 gallons. This is more than six times the amount spilled in the widely known *Exxon Valdes* incident. In this spill, the ship ran aground and dumped 10,800,000 US gallons (41,000 m') of oil into the ocean in March 1989. Despite efforts of scientists, managers, and volunteers over 400.000 seabirds, about 1,000 sea otters, and immense numbers of fish were killed. Considering the volume of oil carried by sea, however, tanker owners' organizations often argue that the industry's safety record is excellent, with only a tiny fraction of a percentage of oil cargoes carried ever being spilled. INl FR l'ANKO - the international Association of Independent Tanker Owners - has observed that "accidental oil spills this decade have been at record low levels - one third of the previous decade and one tenth of the 1970s - at a time when oil transported has more than doubled since the mid 1980s."

Oil tankers are only one source of oil spills. According to the tnitcd States Coast Guard, 35.7% of' the volume of oil spilled in the United States from 1991 to 2004 came from tank vessels (ships/barges), 27.6% from lacilitics and other non-vessels, 19.9% from non-tank vessels, and 9.3% from pipelines: 7.4% li-om mystery spills. On the other hand, only 5% of the actual spills came from oil tankers, while 51.8% came from other kinds of vessels. The detailed statistics for 2004 shown in the table below show tank vessels responsible for somewhat less than 5% of the number of total spills but more than 60% of the volume. In summary, spills are much rarer but much more serious on tank vessels (tankers) than on non-tank vessels.

The International Tanker Owners Pollution Federation has tracked 9351 accidental spills that have occurred since 1974. According to this study, most spills result from routine operations such as loading cargo, discharging cargo, and taking on fuel oil. 91% of the operational oil spills are small, resulting in less than 7 metric tons per spill. On the other hand, spills resulting from accidents like collisions, groundings, hull failures, and explosions are much larger, with 84% of these involving losses of over 700 metric tons.

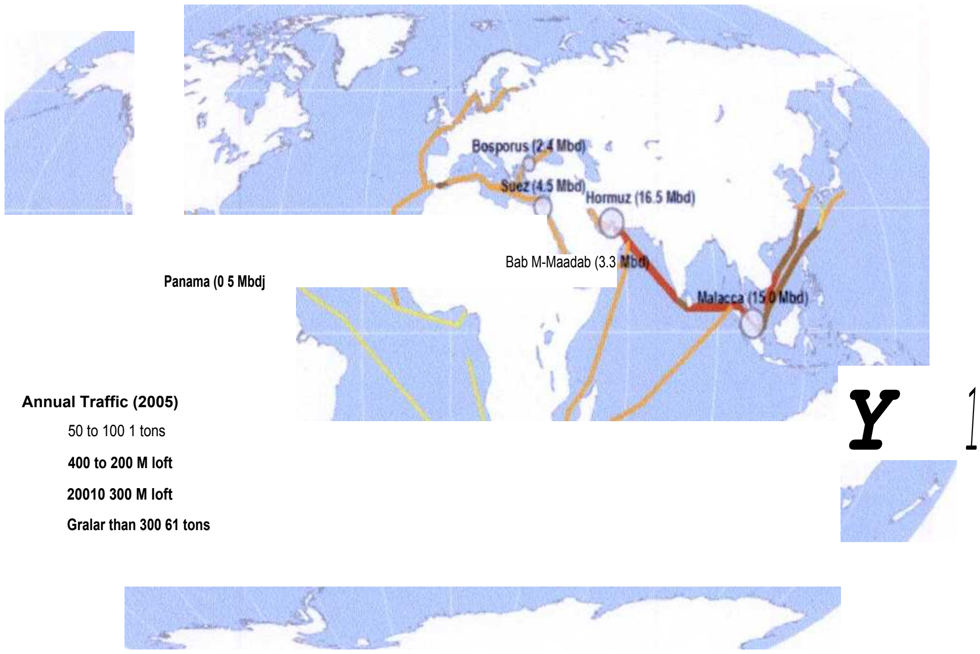
2.6 Characteristics of Crude Oil Transportation

In 2005, 2.42 billion metric tons of oil was shipped by tanker. 76.7`%, of this was crude oil, and the rest consisted of refined petroleum products. '['his amounted to 34.1% of all seaborne trade for the year. Combining the amount carried with the distance it was carried, oil tankers moved 11,705 billion metric-ton-miles ofoil in 2005.

By comparison, in 1970 1.44 billion metric tons of oil was shipped by tanker. This amounted to 34.1% of all seaborne trade for that year. In terms of amount carried and distance carried, oil tankers moved 6,487 billion metric-ton-miles ofoil in 1970.

2.7 Oil Transportation and Major Routes

The bulk of the oil transported (62%) is using maritime transportation. The Persian Gulf is a major origin and frorn this point maritime routes are reaching Europe through the Suez Canal, Japan through the Strait of Malacca and North American through the Cape of Good Hope. Major continental movements involve the Russian and former Soviet Republic's petroleum shipped to Western Europe by pipeline and Alaskan and Canadian petroleum shipped to the United States also by pipeline. Other important oil shipments are from Africa to North America and Europe, from the North Sea to Europe and from South America to North America.



Source: Adapted from The International Tankers Owners Pollution Federation Limited & Energy Information Administration, World Oil Transit Chokepoints.

Chapter 3: International Conventions on Oil Pollution and Control

3.1 Oil Pollution – Background

3.1.1 Introduction

During the last few decades the pollution of the marine environment has become a matter of increasing international concern. Most of the pollution comes From land-based sources, which includes by-products of industry, run-off' from agricultural pesticides and effluents discharged from urban areas. Ilovtievcr. shipping and maritime activities also cause serious environmental damages. specially with oil spills as a result of both normal operations and accidents. The Tanker I orrey Canyon (1967), the Tanker Amoco Cadiz (1978) and the "tanker Fxxon Valdez. (1989) disasters are examples. In Bangladesh too, there were cases of ships collision and accident resulting into oil spill in the past. Foreign 'tanker Filothei and Bangladesh Flag Carrier owned by BSC are the examples of grounding resulting in oil spill. Bangladesh Govt. accordingly moved to have legal and organization arrangements to control the incidents of oil spill, if any.

3.1.2 Development and Evolution of International Conventions

The world's first oil tankers appeared in the late 19th century and carried kerosene for li ghting, but the invention of the motor car fuelled demand li)r oil. During the Second World War, the standard oil tanker was the T2, 16,400 tons deadweight. but tankers grew rapidly in size from the 1950s onwards.

The first 100.000-tonne crude oil tanker was delivered in 1959 to cover the route from the Middle East to Europe round the Cape of Good I lope (thereby avoiding the Suez Canal which had been temporarily closed following political conflicts in 1956). Shippers saw economies of scale in larger tankers and by the mid-I960s, tankers of 200,000 tons deadweight- the Very Large Crude Carrier or VI,('(' - had been ordered.

The potential for oil to pollute the marine environment was recognized by the International Convention for the Prevention of Pollution of the Sea by Oil. 1954 (01LPOL 1954). The 01LPOL Convention recognized that most oil pollution resulted from routine shipboard operations such as the cleaning of cargo tanks. In the 1950s, the normal practice was simply to wash the tanks out with water and then pump the resulting mixture of oil and water into the sea.

3.2 Technical Understanding of the Problem and Chronology of Major Disasters and Adoption of Convention and Amendments

3.2.1 Marine Environmental Protection from Oil Pollution

It has been recognized that marine pollution from ships, which allccts so many nations can only be satisfactorily tackled through international cooperation. The International Maritime Organization (IMO), which is a United Nations body established in 1948, has formulated international conventions and agreements in this regard. The journey started since 1967 with the accidental oil spill of ' Torrey Canyon', which is still on through amendments and adoptions of new clauses into the mainframe Convention. For better understanding of the aspects of oil spills and their impacts and consequences resulting in the adoption of conventions, chronological progression of the process have been described below:

3.2.1.1 `Torrey Canyon' Disaster and Adoption of Convention

Although the OILPOL Convention had been ratified, pollution control was at the time still a minor concern for IMO, and indeed the world was only beginning to wake up to the environmental consequences of an increasingly industrialized society.

But in 1967, the Torrey Canyon ran aground while entering the I :ngglish Channel and spilled her entire cargo of 120,000 tons of crude oil into the sea. This **resulted in the biggest oil pollution incident ever recorded up to that time.** T**he incident raised questions about measures then in place to prevent oil pollution from ships and also exposed deficiencies in the existing system for providing compensation following accidents at sea.**

It was essentially this incident that set in motion the chain of' events that eventually led to the adoption of International Convention for the Prevention of Oil Pollution

from Ships MARPOL - **as well as a** host of Conventions in the field of' liability and **compensation.**

1973 ***International Convention*** *for the* ***Prevention of Pollution*** *front Ships*

At the same time, a series of tanker accidents in 1976-1977, mostly in or near United States waters and including the stranding of the Tanker Argo Merchant. led to demands for more stringent action to curb accidental and operational oil pollution adopting the 1973 International Convention for the Prevention of Pollution from Ships. The Argo Merchant ran aground off Massachusetts in December 1976. It was a small tanker, carrying 27,000 tons of oil, but caused huge public concern as the oil slick threatened New England resorts and Georges Bank fishing ground.

1978 Conference ***on Tanker*** *Safety* ***and Pollution I'revention***

The Conference, **in February 1978, adopted** a protocol to the 1973 MARPOL **Convention**, **absorbing the parent Convention and expanding on the requirements for tankers to help make them less likely to pollute the marine environment.**

The Protocol expanded the requirements for segregated ballast tanks to all new crude oil tankers of 20,000 dwt and above and all new product carriers of 30,000 dwt and above. The Protocol also required segregated ballast tanks to be protectively located, in other words, placed in areas of the ship where they ,vill minimite the possibility of and amount of oil outflow From cargo tanks after a collision or grounding.

Additional measures for tanker safety were incorporated into the 1978 Protocol to the International Convention for the Safety of Life at Sea (SOLAS), 1971. "These **included the requirement for inert gas systems** (**whereby exhaust gases**, **which are low in oxygen and thus incombustible**, **are used to replace flammable gases in tanks) on all new tankers over 20,000 dwt and specified** existing **tankers. Both the 1978 MARPOL and SOLAS Protocols were seen as major steps in raising construction and equipment standards for tankers through more stringent regulations.**

If the world needed further reminder of the need for strict regimes to control oil pollution, it got it just one month after the 1978 Conference, when the **Amoco Cadiz** ran aground off Brittany, giving France its worst oil spill ever. "I'he tanker. filled with 223.000 tons of crude oil, lost its entire cargo, covering more than 130 beaches in oil. In places, **the oil** was up to 30 cm thick.

The seriousness and importance and urgency of realization of overall impacts and consequences of the series of disasters ultimately prompted sufficient states to ratify MARPOL by October 1982, and the MARPOL 1973/78 Convention entered into force on 2 October 1983.

Since the Convention **entered into** force. there have been a number of amendments to **the Convention** - see MARPOL 73/78.

3.2.1.2 Exxon Valdez Disaster and Adoption of Convention and Amendments

It was another tanker accident which led to one of the most important changes to be made to Annex I of the Convention since the adoption of the 1978 Protocol.

In March 1989, **the Exxon Valdez**, loaded with 1,264.155 barrels of crude oil, ran **aground in** the northeastern portion of Prince William Sound, spilling about one-fifih of its cargo. It was the largest crude spill, to date, in US waters and - probably the one which gained the biggest media coverage to date. The U.S. public demanded action - and duly got it.

The United States introduced its Oil Pollution Act of 1990 (()PA 90), making it mandatory for all tankers calling at U.S. Ports to have double hulls.

3.2.1.3 The Erika **Disaster** and Adoption of Convention

On 12 December 1999 the 37,238-dwt tanker **Erika** broke in two in heavy seas off the coast of Brittany, France, while carrying approximately 30,000 tons of heavy fuel oil. Although the crew were saved, some 14,000 tons of oil were spilled and more than 100 miles of Atlantic coastline were polluted.

As a result of the **Erika** disaster, proposals were submitted to the IMO to accelerate the phase-out of single-hull tankers contained in the 1992 MARPOI, amendments and the amendments to MARPOL 73/78 Convention were adopted in Apri1200 1.

3.3 Salient Features of MARPOL 73/78 and Annexure

3.3.1 Preventing Operational Pollution

- ***International Convention*** *for the Prevention of'Pollution fi•orn Ships, 1973. as modified by Protocol of 1978 (MARPOL* 7317$: **Prevention or Control of the Pollution by Oil, Noxious Liquid Substances, Packaged Goods and Non-Liquid Substances, sewage and Garbage.**
- ***Convention on the Prevention*** *of Marine Pollution by 1)umpin, of Wastes and* ***other Materials****, 1972 (The London Convention):* **Regulate the deliberate disposal at sea of dredged material and land-generated waste. Dumping of certain hazardous materials such as oil and petroleum products, mercury, cadmium wastes, plastics, etc are prohibited.**

3.3.2 Reducing the Damage of Accidents

- ***International Convention*** *on Oil Pollution Preparedness, Response and Co-* ***operation****,* ***1990*** *(OPRC):* **Provide a global framework for international co-operation in combating major incidents or threat of' marine pollution. Governments are required to establish a national system for responding promptly and effectively to oil pollution incidents. 'I'bis includes, as basic minimum, the creation of a national contingency plan, designating national authorities and operational focal points responsible fir oil pollution preparedness and response, reporting and handling requests fir assistance.**

3.4 Environmental Legislation on Marine Pollution in Bangladesh

Department of Shipping – It is **an Executive Agency promulgated by Presidential Ordinance 1972, under the Ministry of Shipping** with wide-**ranging regulatory functions like implementation and enacting national and international laws and conventions relating to marine transportation, maritime** safety **administration,**

registration of ships, survey etc. The Department of Shipping is also responsible for drawing necessary **acts and regulations** applicable to the country's maritime sector **including those regarding** safety of shipping and control of marine pollution from ships.

However, in absence availability of any specific national rules and regulations in force with respect to Prevention of Pollution from Ships other **than International Conventions against oil pollution from ships to which Bangladesh is a member state, there are a number of national laws which merely outline provision for prevention pollution under the Environment Conservation** Act (ECA), 1995 to **vwhich Department of Environment** (**DoE), the Department of Shipping and Coast Guard authorities are responsible for preventing marine pollution along with the Port Authorities and the** Navy for **necessary implementation and enforcement of' the prevailing rules and regulations.**

In 1992, the National Environmental Policy Act was adopted to maintain a balance between economic development and environmental protection.

1. **The Environmental Conservation** Act. 1995 ([CA) is the **main legislative framework document relating to environmental protection in Bangladesh. In order to enforce this Act, the Environment** Conservation **Rules (ECR) were promulgated in 1997. These rules** stand for:

i) the National Environmental Quality Standards for ambient air, various types of water, industrial effluent, emission, noise, vehicular exhaust, etc.,

ii) required procedures to obtain environment clearance. and

iii) IEE/EIA requirements.

2. Chittagong Port Ordinance, 1976: Penalty for pollution -

Any person who throws or allows to fall into water, shore, hank or any land within the limit of the port any goods, ballast, ashes or anything causing pollution of water or environment shall he punishable with fine which may extend to one lac taka'.

3. Inland Shipping Ordinance, 1976 and Act, 1990:

'No person shall, by discharge from Inland vessel or Inland Vessel Facility or Inland Vessel Activity causes pollution of Inland Water'.

4. Marine Pollution Ordinance, 1977:

Provides control for oil or pollutants discharged, spilled or dumped into Bangladesh water from ships, ship-shore transfer. ports, exploration of sea bed, pipe lines and ollshorc installations. It also makes mandatory provision of establishing Oil Spill Contingency Plans.

5. **Environmental** Control **of Inland Water** Transport, 1997:

`**Best Practice of Environmental Management**' For the purpose of **these rules**, **the best practice of Fnvironmental Management is the management of inland vessel**, port, ship **related** Cacility **and ship related activity to achieve and ongoing minimization of environmental harm through** cost effective **measures against the appropriate** existing **international and national standard.**

Chapter 4: Environmental Legislation on Marine Pollution in Bangladesh

4.1 Technical Understanding of the Problem

It has been recognized **that marine** pollution from ships. which affects so many **nations, can** only be satisfactorily tackled through international cooperation. The **International** Maritime Organization (IMO), which is a United Nations body, established in 1948, has formulated **international** conventions in this regard which include:

4.1.1 Preventing Operational Pollution

1. ***International Convention** for the Prevention of Pollution frorrr Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73i7^).* **Prevention or Control of the Pollution by Oil, Noxious liquid substances**. packaged **goods and non-liquid substances**, **sewage and** Garbage

Convention on the Prevention of-Marine Pollution by Dumping of Wastes and Other Matter, 1972 (The London Convention): Regulate **the deliberate disposal at sea of dredged material** and land-generated waste. Dumping of **certain hazardous materials such as oil and petroleum products, mercury, cadmium**, **radioactive wastes, plastics**, etc are prohibited.

4.1.2 **Reducing the Damage** of Accidents

International Convention on Oil Pollution Preparedness. Response and Cooperation, 1990 (OPRC:): Provide a global framework for international co-operation in combating major incidents or threats of marine pollution. Governments are required to establish a national system for responding promptly and effectively to oil pollution incidents. 'Ibis includes, as a basic mininuim, the creation of national local points responsible for oil pollution preparedness and response, reporting and handling requests for assistance.

4.2 National Legislation on Marine Pollution

In 1992, the National Environmental Policy Act was adopted to maintain a balance between economic development and environmental protection.

The Environmental Conservation Act, 1995 (L'CA) is the main legislative framework document relating to environmental protection in Bangladesh. In order to enforce this Act, the Environmental Conservation Rules (ECR) was promulgated in 1997.
These rules stand for:

i) the National Environmental Quality Standards for ambient air, various types of water, industrial effluent, emission, noise. vehicular exhaust. etc.,

ii) required procedures to obtain environment clearance, and

iii) IEE/EIA requirements.

Resource management laws are provided for the sectoral functions of various ministries and public agencies. The Department of Environment (DOE.), the Department of Shipping and Coast Guard Authorities arc responsible for preventing marine pollution along with the Port Authorities and the Navy.

Although Bangladesh has formulated some national environmental legislation, yet most of the environmental legislation remains non-functional in mam instances for a number of factors, owing mainly to institutional capacity constraints. As for international instruments, Bangladesh has been slow to adopt relevant maritime conventions. In relation to oil and dumping of' solid waste and dredging spoils, Bangladesh has adopted only the outdated Oil Pollution Convention (I954), neither the MARPOL 73/78 nor the OPRC 1990 has yet been signed. Of course, Bangladesh has lately become a signatory to South Asia Co-operative Environment Programme (SACEP) and South Asian Regional Seas Programme (SARSP).

There is an urgent need to review the legal and regulatory instruments and standards in place or being drafted for dealing with oil spills and other port and shipping related environmental management issues, particularly in relation to adoption of international conventions. Preparation of a national oil spill contingency is being looked as the first national policy in this respect.

In order to protect the whole coastal area of Bangladesh including that of the Chittagong Port for its ever increasing trend of shipping traffic and Mongla Port with the location of the SRF, which is important area not only from the point of view of environmental protection, but also from the point view of socio-economical upliliment, strengthening the capacity of CPA and MPA for effective mitigation, monitoring and enforcement of appropriate regulations will he of prime importance.

4.3 Territorial Waters and Jurisdiction of Bangladesh

The jurisdictional territory of waterway control in Bangladesh has also been investigated. The two international ports, Chittagong and Mongla, areas of which as in their respective ordinances are controlled by CPA and MPA. Coast Guard controls all coastal area including port areas and the main trunk waterways Chittagong - Dhaka and Mongla - Dhaka. Specially for the purpose of mitigating all sorts of environmental hazards.

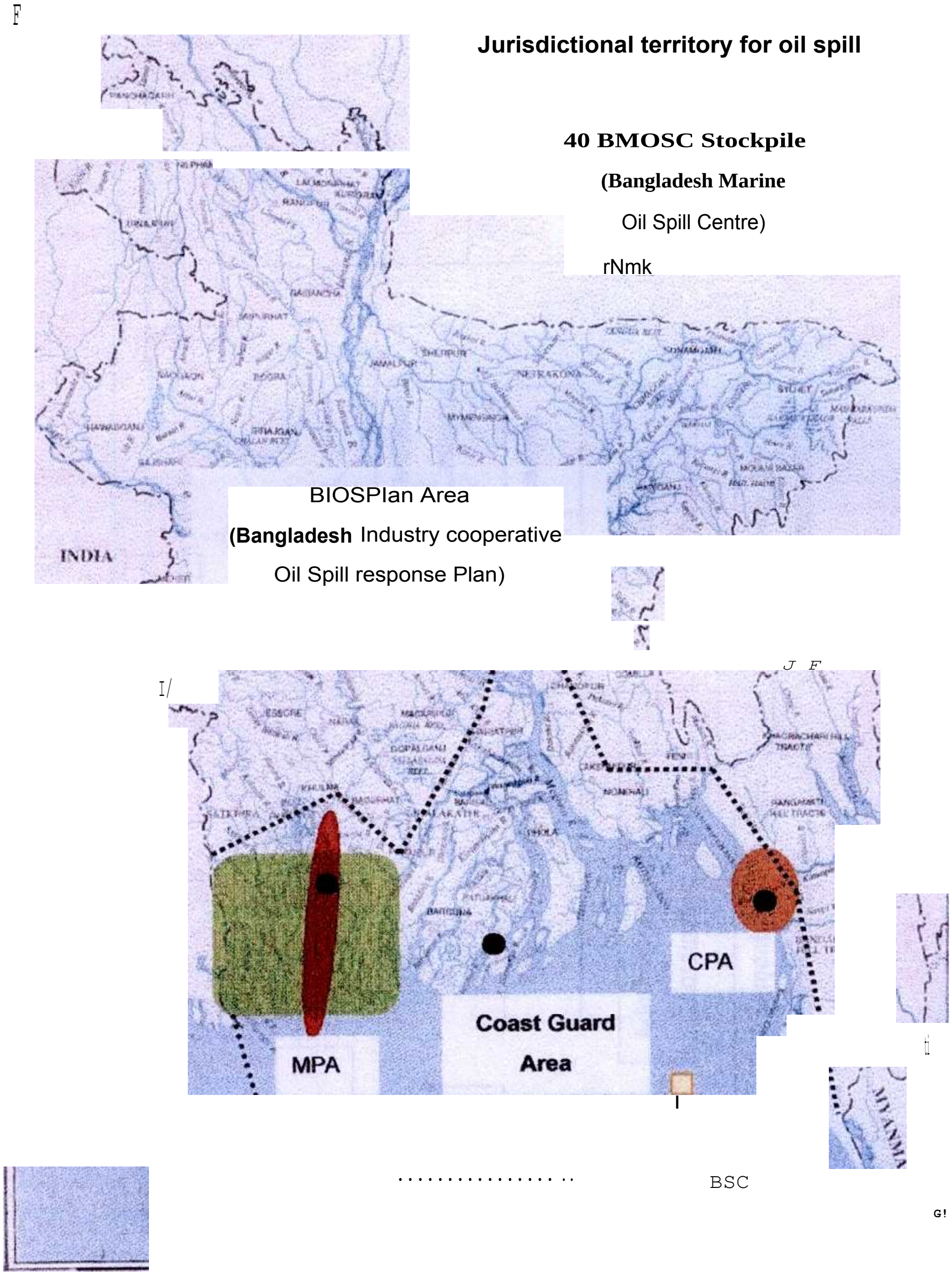
According to their regulations, they have a responsibility fin response of oil spill if it happens in their territory. But, the jurisdictional authority of offshore anchoring point and tanker waterway along coast is not clear, because BIWI'A control not only tanker transferring inland water way but also along coast way. These clarifications are necessary for a worth while national contingency plan.

Traffic via water ways is controlled by the following authorities:

Water way	BIWTA	CPA	MPA	Coast **Guard**	**Remarks**
Inland waterways	•				
Port Area		•			F,ach port
Chittagong-Cox's Bazar	•				
Chittagong Chowkighata	•			•	
Chittagong – Hiron Point					
Anchoring point--Chittagong					

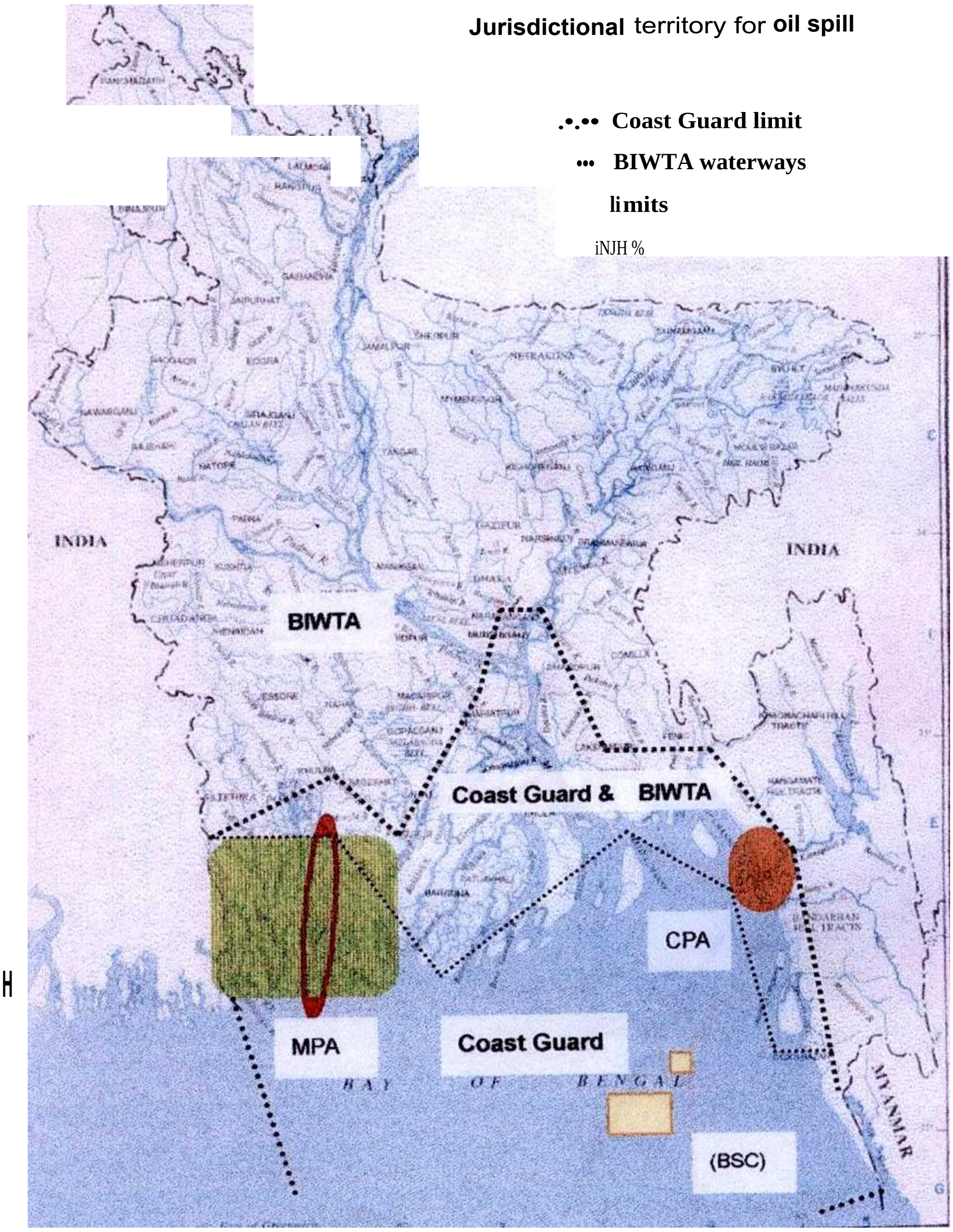
About national territory of ocean side, Bangladesh's position is shown below. It is therefore, obvious that any oil spill incident beyond Bangladesh territorial waters will call for regional and international co-operation for speedy measures of mitigation.

	Territory	Remarks
Base line	The depth of water 60 I (18 m) line	As shoreline
I erritorial water	12 nautical mile from base line	I'o ocean side
Administrative limit	24 nautical mile from base line	fo ocean side
Economic zone	250 nautical mile from base line	fo ocean side
Border line limit	According to international Convention	India, Myanmar



Source: **Bangladesh Petroleum** Corporation

Bangladesh Territorial Water - Boundary



Source: Bangladesh Petroleum Corporation

Bangladesh Domestic Jurisdictional Territory of Control

4.4 Coastal Zone Management and Law

1. Coastal zone management included healthy environment of the sea coast and the structures abetting the sea coast such as harbor, port etc., and coastal waters such as the internal waters, territorial sea, continental shelf and the exclusive economic zone within the coastal state's jurisdiction.
2. The successful management of the sea coast and its ecological development depends upon the sound and scientific coastal state regulations affecting the exploration and exploitation of the living and non-living resources in coastal waters and the activities ofthe coastal state and other states on the shore.
3. Legal regulation of the various activities of the coastal states and other states entering the coastal waters of a particular state where the coast line pertain rich ecological heritage. Law of the Sea plays a significant role in creating the environment and for achieving sustainable development by means of appropriate use of the coastal state waters and its living and non-living resources.

4.5 Legislative Measures to Preventing and Control of Marine Pollution – National and International

There are a number of legislations in force in various nomenclatures nationally and internationally -

1. The Water Pollution Prevention and Control Act
2. The Territorial Waters. Continental Shelf. Exclusive I .conomic Zone and other Maritime Zones Act
3. The National Coast Guards Act
4. Coastal Regulation Zone Notification etc.
5. International Convention for the prevention of pollution of the sea by oil, 1954 which was later amended in 1969 and 1971, 1973, 1978.
6. Geneva Convention, 1958.
7. International legal conference on marine pollution damage. 1969.
8. Convention on the establishment of an international fund for compensation for oil pollution damage, 1971.
9. Convention for the prevention of pollution from ships, 1973.
10. Third United Nations conference on the Iaw of the Sea, 1973- 1992.

Chapter 5: Marine and Coastal Environments: Asia Pacific, South Asia and Bangladesh Context

5.1 General Context

Oil Pollution of the marine environment has been an issue of considerable national and international concern. Countries around the Arabian Sea mainly Pakistan and India and the Indian Ocean covering India, Maldives. Sri Lanka, Bangladesh and Myanmar rely heavily on the marine environnicnt for trade and commercial operations. Further, two major oil choke points of the world Strait of I lormuz and Strait of Malacca lie on the west of the west and cast coasts of India. Due to the narrowness of these lanes, the routs are accident-prone. Moreover. import of oil and gas is growing faster than the demand, particularly in the developing countries in the region. The world's demand For petroleum products has been estimated to go up from 84 million barrel/day in 2005 to 1 16 million barrel/day in 2030. The risk of major oil spill occurring along the west and east coasts of India are considerably higher now, as there has been a significant increase in all types of marine trade. A major oil spill could cause widespread ecological damage, and cripple or destroy marine commercial operations. Therefore, continued discharge of oil into sea can pose a potential risk of severe pollution to the sensitive coastal ecosystem.

Oil spills not only affect ambience of the beaches threatening overall tourism sector, which is one of the main employment-generating industries, but are also known to affect the coastal ecology, fishery and agriculture on it long-term basis.

In contrast to the increase in oil consumption, resulting in increase in maritime transportation, incidents of accidental spill have shown a decrease globally since the 1970s, thanks to implementation of various preventive measures. Tanker spills annually account for 12% of the oil entering the sea and a total 53I spills have been reported (J *Hazard. Maier., 2006)* internationally from 1979 to 2004. Among the accidental tanker spills, 34% occurred due to grounding of vessel and 28.3% due to collisions. According to Clark, R.B. (ed.), Oxford, UK. 1986, most of the oil affecting the marine ecosystem is derived from tanker operations and accidents. I lowever, compared to the decrease in oil spills incidents globally. the number of tanker spills/accidents has increased along the coastal regions. Of the total observed spills. 70% were reported from the west coast of India.

Apart from accidental spills, oil pollution occurs during routing operations such as loading, discharging and bunkering, which are normally carried out in ports or at oil terminals arising concern about the number of illegal discharges from the large volume of shipping within the region. The region has had so far only relatively minor oil spills in coastal waters, primarily from tanker accidents. The possibility however, of a major oil spill occurring along the coasts is considerably higher today, as there has been a significant increase in all types of oil tankers/bulk carriers/container ships passing through the Indian Ocean.

5.1 General Terminology

How can marine pollution be defined: Marine pollution is defined as discharge of waste into the sea resulting in harm to living resources. hazards to human health, hindrance to fishery, agriculture, tourism, economy and impairment of quality for use of seawater. Marine pollution is associated with the changes in the physical, chemical and biological conditions of seawater.

5.2.1 Sources of Marine **Pollution**

The major sources of marine pollution can be categorized as under:

1. **Land based pollutants - Disposal of sewage, industrial effluents and agricultural wastes**
2. Operational **and accidental discharge of ship borne pollutants**
3. **Exploration and exploitation of marine resources**
4. **Disposal of radio active waste after** the usage of nuclear energy
5. Military **use of the sea**
6. **Maritime accidents due to collision, fire, explosion** or grounding which **results in the release of oil, either from the ship or from the cargo tank**
7. **International discharges** of oil or oily waste **From the pumping of bilges or deballasting cargo tanks or from tank washing**

5.2.2 Causes of Marine Pollution

I. Pesticides and insecticides are used in agriculture and tons of synthetic detergents are consumed for washing and cleaning purposes every year. About 25% of these chemicals can be expected to find their way into the coastal marine environment.

2. Ocean disposal is the convenient method of pesticide waste disposal for manufacturing plants located in the coasts. The large amounts of' suspended solids deposition may he detrimental to the biota that grows on the seabed and it may be difficult for seabed dwelling organisms to survive.

3. The fertilizer industry, along with chemical and petro-chemical industries also causes water pollution. Fertilizer factories produce large quantities of wastes, which contain a variety of substances such as oil, carbon slurry, ammonia, urea, ammonium sulphate, phosphate and fluorides, acid, alkali, arsenic, caustic, potassium carbonate etc. which create water pollution.

4. Major rivers, the Arabian Sea, the Bay of Bengal and the Gulf of Mannar are all being polluted by fertilizer industries situated therein.

5. Oil spills due to routine operation at sea and while in terminals. tank washing from tankers including from super oil tankers and blow outs from off shore platform pose a real threat to harbor, beaches and coasts destroying life and spoiling places of livelihood, recreation, fishing and agriculture.

6. Ship breaking industry creates numerous hazards liar the coastal and marine environment. Due to the activity of ship breaking. large number of dangerous pollutants including toxic waste, oil and heavy metals arc released to the waters and seabed. While most of the oil is removed before a ship is scrapped. sand used to mop up the remaining oil is thrown into the sea. High concentration of oil and grease are found in the coastal waters, chocking marine life.

7. Cooling water from thermal power plants has also adverse effects on the coastal marine fauna. '['lie largest single source of radioactive liquid waste is probably the water used for cooling reactors.

5.3 Marine and Coastal Zones – Asia Pacific Context

The Asia-Pacific marine environment comprises three major sea regions, namely the South Asian, The East Asian and the Pacific Islands region. The South Asian seas region includes Bangladesh, India, the Maldives, Pakistan and Sri Lanka, as well as the bordering country Myanmar. The East Asian seas region covers six ASEAN countries, i.e. Brunei Darussalam, Indonesia, Malaysia, the Philippines, Singapore, and Thailand, as well as bordering countries, i.e. Viet Nam, Cambodia and the People's Republic of China. The Pacific Island sea region, which is characterized by coral reefs and lagoons, sea grass beds and mangroves, is partially surrounded by Asian, Indian and Australian land masses.

A large majority of the population in the region resides along the coasts and one quarter of the world' **s 75 largest cities are situated near**, **or on**, **the region's coastlines** (ESCAP, 1995). Growth **rates of coastal populations are generally higher than the national average as a result of migration to coastal urban areas and industrial centers. Most of these large cities and industrial areas are located** in highly **productive, low lying estuarine areas**. **The coastal characteristics of selected Asia-Pacific countries are shown below:**

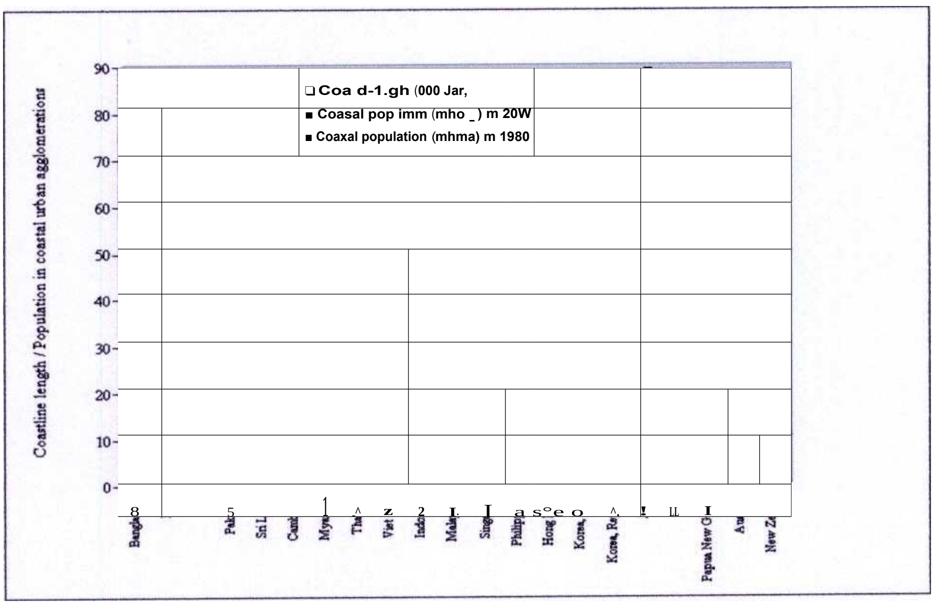


Figure 1.16: Coastal characteristics of selected countries of Asia-Pacific.
Sou, WRI(1994)

The marine resources of the region are economically important to most countries. Forty seven per cent of world fisheries production occurs in this region, of which marine and freshwater fisheries account for 76 per cent and 24 per cent respectively. This region is also the centre of global mariculturc (87 per cent of total world production) (FAO/RAPA, 1994). which has major consequences for coastal habitats and coastal water quality. For insular and archipelagic states. marine resources are the key source of external earnings for development, and marine-based tourism is playing an increasingly important role in the economy of such countries. Most countries in the region rely almost exclusively on fisheries products for dietary protein, where it is also evident from the trends that in almost all of the sub-regions the marine fish catch are steadily increasing.

Coastal and marine water pollution in this region is mainly due to **direct discharges from rivers, surface run-off and drainage from port areas**, domestic and **industrial effluent discharges through outfalls and various contaminants from ships**. **Rivers in this region are generally heavily contaminated with municipal** sewage, **industrial effluent and sediments**. **Asian rivers account for nearly 50 per cent of the total sediment load (13.5 billion tones per year) transported** by the **world's** rivers (UNIT, 1992). And **unfortunately**, **most of the coastal cities in this region discharge their domestic and industrial wastes directly into the sea without any treatment.**

As much as 70 per cent of the waste effluent discharged into the I'aci f is Ocean has no prior treatment (Fuavo, 1990). Over 40 per cent of marine pollution in the region is derived from land-based activities via riverine discharge and maritime transport contributes a further 12 per cent (Weber, 1993).

5.4 Marine and Coastal Zones – South Asian Context

Bangladesh in the South Asian Seas region including countries in the coasts of' Indian Ocean and Bay of Bengal are no exception with its continuous pollution to marine environment due to considerable growth in use of pesticides and fertilizers and industrialization and lesser control over discharge without treatment of effluents have put the marine environment more threatened and vulnerable.

The major sources of heavy metal contamination are industrial effluents and dumping of land-based solid waste into the sea. In India, for example, exceptionally high concentrations of lead (820 micrograms per litre) and cadmium (136 micrograms per litre) have been observed in the Bombay coast and the mercury concentration was 778 micrograms per litre. In Pakistan, heavy metal contamination has been detected in water and sediment from the coastal area within the mouth of the Indus River (Tariq et al., 1993). Moreover, there is increasing evidence that these toxic substances are getting into the food chain.

Marine pollution also arises from sea-based activities, including marine transportation and offshore mineral exploration and production activities. "I he offshore activities in the area, particularly the Bay of Bengal are in increase at recent time due to exploration of both natural gas and oil. Continental shelves and deep sea beds having been found rich in such mineral resources potential, all the countries namely India which has already commenced explorations and Bangladesh and Myanmar both are in the processes letting out their respective block to foreign oil and gas companies. the activities thereof pose further risk hazards to the region out of possible oil spillage.

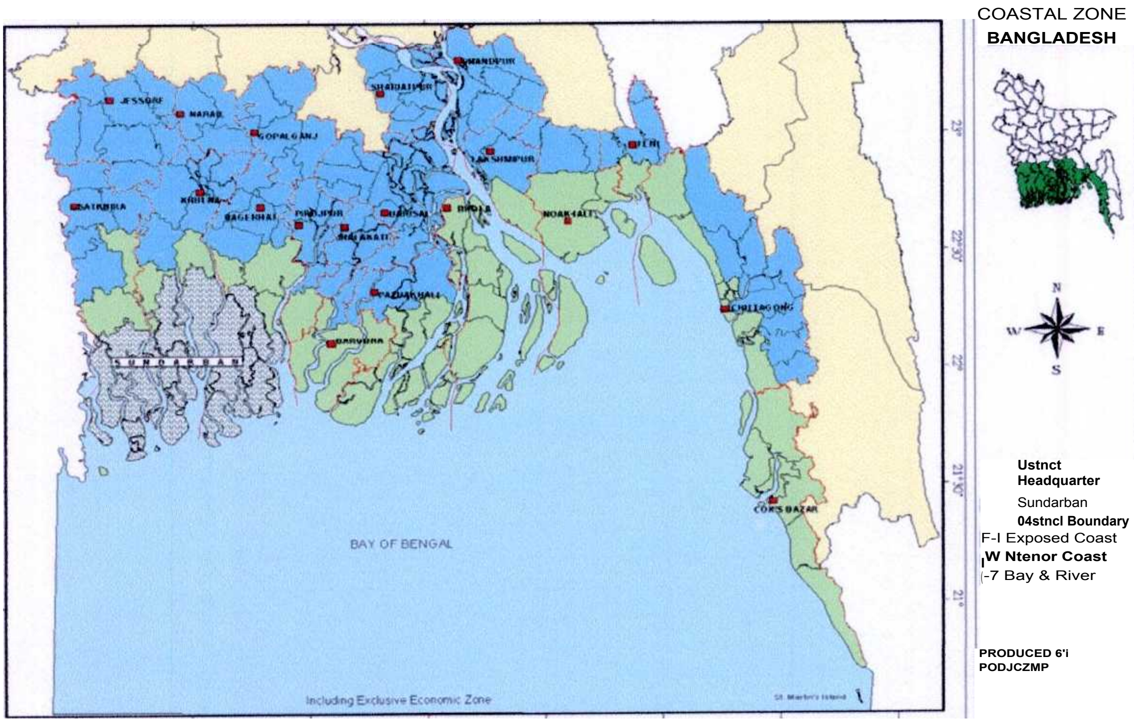
There are also frequent reports of incidents of accidental oil spills from ships in the region. In the Straits of Malacca alone, 490 shipping accidents were reported between 1988 and 1992, resulting in a considerable amount ofoil spillage at sea (Straits 'l'imes, 1993). Beach tar is also considered a severe problem along the west coast of India, with total deposits of up to 1,000 tonnes a year (GESAMP. 1991). In the port of Chittagong in Bangladesh, it is estimated that about 6,000 tonnes of crude oil are spilled a year and crude residue and wastewater effluent from land-based refineries amount to about 50,000 tonnes per year (Khan, 1993). Approximately 5 million tomes of oil enter the Arabian Sea each year and the Bay of' Bengal receives 100,000 from similar sources (ESCAP, 1995). Oil pollution from shipping and offshore oil rigs is also a concern in the East Asian seas.

The increased use of agro-chemicals in this region also contributed to marine pollution. Fertilizer consumption in the South Asia and the Pacific Region rose 74 per cent, from 33.3 million tones to 57.8 million tones. over the period 1982-92 (ISCAP. 1995). The use of pesticides to enhance agricultural productivity appears to he increasing, specially in the developing countries including Bangladesh in the region. For example, in the South Asia, India alone uses 55,000 tonnes of pesticides a year, of which about 25 per cent are thought to end up in the sea (WRPUNFP, 1990) An estimated 1,800 tonnes of pesticides enter the Bay of Bengal each year (I Iolmgren, 1994). The increased use of pesticides in addition to other causes of pollution has become a serious potential of risk of hazards to marine environment and the risk finds no mitigation rather worsening the overall situation.

There is a substantial loss of coastal habitats in South-Fast Asia as mangroves are used for the construction of shrimp ponds and for paddy rice cultivation. 'T'hese activities affect, indirectly, commercial demarsal fisheries that rely on the mangroves as nursery areas. Thailand and Philippines are typical examples, where some 208,218 hectares and 200,000 hectares (during 1961-93) respectively, were cleared (GESAMP, 1993). Identical problems resulting from shrimp culture have occurred in Bangladesh, India and Sri Lanka. Notably, one of such destructive sequence of events in the Chakaria Sundarbans in eastern part of Bangladesh, which have been almost completely cleared for aquaculture (ESCA1 . 1995), and similarly the western part of the country's coast is in verge ol' destruction.

"Tourism, tourism encroachment and recreational activities can themselves be a threat to marine and coastal environments. The construction activities which accompany most tourism developments, such as hotels, beach clubs and marinas, have a range of' direct and indirect impacts on coral reefs through inlilling. dredging and the resuspension of contaminated silts. And Bangladesh with is overall developments in all sectors gradually becoming more vulnerable to multiple risk of hazards.

5.5 Coastal Zone of Bangladesh



Source: PDO - ICZMP

The coastal zone of Bangladesh can be divided in to three regions as follows:

5.5.1 The Eastern Zone

Morphologically the eastern coastline of Bangladesh from the big Feni river to Badar Mokam (southern tip to the mainland) along Chittagong can be classified as a `Pacific Type' coast running parallel to the young (Tertiary) folded hill ranges. The east coast is regular and unbroken and is protected along seacoast by mud flats and submerged sands. A continuous strip of sand (sandy beach) lies from Teknaf (Myanmar Border) to Badar Mokam and form one of the longest beaches of about 145 km. The smaller rivers and the Chakaria and Teknaf mangrove forests of the eastern region (Karnafuli, Sangu, Matamuhuri and Naaf) play an important role in determining the coastal ecosystem.

5.5.2 The Central Region

The region begins from the Tebegins from the Tetulia river to the big Feni river estuary including the mouth of the Meghna river upto the confluence of the Padma (Ganges-Brahmaputra) and the Meghna river near Chandpur. Heavy sediment load and one of the most complex tropical estuarine ecosystems of the world characterize this region. The coastline is most irregular, and consists of'series of' islands, where the rivers are continuously changing their courses. The funnel shaped apex of the Bay of Bengal is relatively shallow surrounded by numerous islands and estuarine channels. The area is dominated by semi-diurnal tidal currents, the maximum tidal range of 5 meters occurs in the Meghna estuary which gradually decreases southwards along the Chittagong coast. Since the last two hundred years the Meghna estuary went through intensive morphological changes with migration and the growth of islands in the southern direction. This region is also subject to the impact of severe natural hazards like cyclone and storm surge causing an innumerable loss of life and property and man made hazards like land based water pollution and marine pollution due to oil spillage from ships.

5.5.3 The **Western Region**

The western region covers the coastline westward from the 'l'etulia River to the international boundary (India) located at the Hariabangha River. The region is mostly covered with dense mangrove forests with deeply scoured tidal channels of the tidal plain overlapping abandoned Ganges delta.

District	Area (Km2)			Ipazilas	
	Total	Exposed	Interior	Exposed	Interior
Bagerhat	3.959	2679	1280	Mongla, Sarankhola, Morrelgan	Bagcrhat Sadar. Chialmari, Fakirhat, Kachua, Mollahal. Ilanyial
Barguna	1.831	1663	168	Amtali, Barguna Sadar. Path irahata. Bamna	13cta!,i
Barisal	2,785		2785		Agailjhara- babuganj- **Ilakcrganj, Gaurnadi.** Ilitla. N **lchcndiganj**, **N-luladi**. **wazirpur, Banari Para. Barisal radar**
Bhola	3403	3403		Bhola Sadar, Burhanuddin, ('liar Fasson, daulatkhan. 1,a molum Manpura, Tazuddin	
Chandpur	1,704		1704		Chandpur Sadar. Faridgauj. Haimchar, I I^Cjiganj, Kachua, Matlab, Shahrasti
Chittagong	5.283	2413	2870	Anowara. Banshkhali. Chittago ng Port, Double Mooring. Mirsharai, I' ahartali. Panchlaish, sandwip. Sil akunda. Patenga, lialisahar. Kotsvali. Rai jid 13ostami	Boalkhali, (handanaish, I_ohagara. Rangunia, C'handoaon, Iatikchhari. Ilathazari, Patiya, Rouzaii. Satkania. Bakalia, Karnatphuli, I.iikIii
Cox's **Bazar**	2,492	2492		Chakaria, Cox's lair Sadar. K itubdia. Ukhia, Moheshkhalt. ramu. Tel	
Feni	928	235	693	Sonagazi	('hhgulnaiva. Fcni Sadar. Parshuram. I)aganhliuivan
Gopalganj	1,490		1490		Gopalganj Sadar. Kashiani, Kotali Para, Mukshcdpur. I ungipara
Jessore	2.567		2567		13ag11 u Para. ('haugachha, .1hikarghachha_ manirampur. Abhavnag!ar, Keshabpur, Jessorc radar. Sharslta
Jhalokati	789		749		.l halokati Sadar, Kanthalia. Nalchity, Rajapur
Khulna	4.394	2767	1627	Dacope, Koyra	Batiaghata. Daulatpur. Dunn!ria. Dighalia, Khalishpur. Khan .Iahal Ali, Khulna Sada, Pail.,;acliha. I'hultala, Rupsha- Sonadanga. Icrokhada
Lakshmipur	1,456	571	885	Ramgoti	I.akshmipur Sada. Kaipur. Ramganj
Na ra it	990		990		I_ohauuara. Narail Sadar. Narigati
Noakhali	3,601	2885	716	Companiganj, Hatiya. Noakhal i Sadar	ChatkhiI. Scnbagh- Itcgumgani

Source: PDO-IC'ZMP. 2003

District and Upazilas of the Coastal Zone of Bangladesh

5.5.4 Extent and Area of Coastal **Belt of Bangladesh**

Source: ABC Maps **of Bangladesh**

Bangladesh has a coastline extending up to 710 km which gives the total length of the boundary between the land area (including islands) and the sea. Along the coast line country's 2 major sea ports are located. Chittagong port on the eastern coast while Mongla Port in the western part of the coast line and hardly 3 km south extends the vast area of Sundarbans. The whole coastline of Bangladesh carries added attention and importance not only due to the situation of the country's two main seaports but situation and existence of the Sundarban Forest which is considered the largest continuous mangrove ecosystem that exists in the world today. It is approximately 10,000 square kilometers in extent, out of which 6017 square kilometers, or roughly 60%, is situated in Bangladesh, while the rest lies in the state of West Bengal of India.

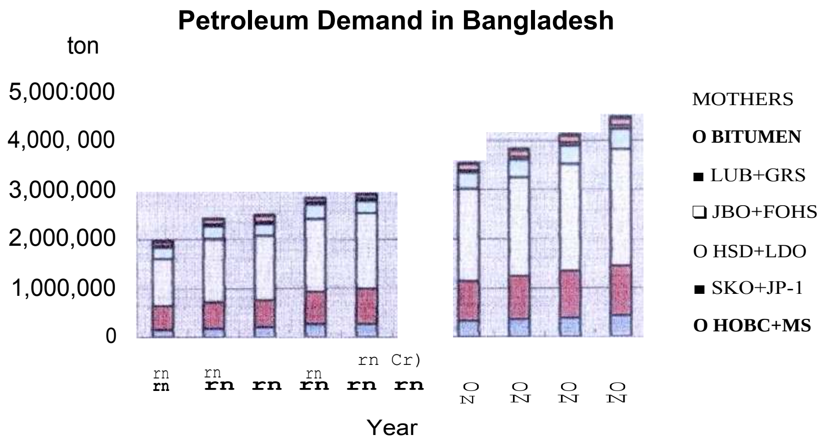
5.6 Background

During the last few decades the pollution of' the marine environment has become a matter of increasing international concern. Most of the pollution comes from land-based sources, which included by-products of industry- run-off Isom agricultural pesticides and effluents discharged from urban areas. Ilowever. shipping activities also cause serious environmental damages. specially with oil spills as a result of both normal operations and accidents. The Torrey Canyon (1967), the Amoco Cadiz (1978) and the Exxon Valdez (1989) disasters are examples. III Bangladesh too, there were cases of ships collision and accident resulting into oil spill in the past. Bangladesh Govt. accordingly moved to have legal and organisational arrangements to control the incidents ofoil spill, if any.

The occurrence of oil spill incidents in different parts of' the world has heightened worldwide concern about the serious environmental consequences. Ships used for transporting the oil account for major oil spillages. In Bangladesh. there are two major international ports - Chittagong and Mongla. Chittagong Port has country's the only oil refinery , with about 5 million metric tones oil imported annually from Persian Gulf ports, including finished oil products. All finished products both refined in FRL (Eastern Refinery Limited) and imported are distributed to various points in Bangladesh including through SRI= (Sundarbans Reserved Forest) and Mongla Port from Chittagong Port. Mongla Port, the other port of the country. has lower direct oil spill risks than Chittagong owing to the lower traffic volume and absence of' an oil refinery. However, Mongla Port is only 3 kilometers north of' Sundarhans Reserved Forest, which has been recently declared a World I leritage Site and has also been the focus of an ADB project; Sundarbans Conservation Project. Mongla Port is reached mainly by a 100 kilometer long navigational channel through the Passer Sibs river system, which runs through the SRF. The throughput of this port is expected to increase considerably, after projected expansions are through thereby making the need for environmental controls, monitoring, and put more emphasis for critical enforcement in the days to cone.

5.7 Oil Demand in Bangladesh

In Bangladesh, petroleum demand is rapidly increasing, and now reaches to almost 7 **million tone**/year. This trend **will continue** with economic growth except few exceptions due to present worldwide recession. With the increase in consumption of petroleum **means increase** in frequency of calling tankers to ports of Bangladesh and similarly inland transportation, and if effective preventive **countermeasures are not** taken and preparedness **in all means are not in place**, the probability of oil spill will remain as a major and serious threat to the country's marine environment.



Data by BPC marketing and distribution division

Source: **Bangladesh Petroleum Corporation**

5.7.1 Characteristic of Petroleum Products

The special characteristic of petroleum demand in Bangladesh is that the greater part of petroleum demand is occupied by diesel oil (HSD and LDO) used as motor and vessel fuel, and only 9% by fuel oil (JBO and HSFO) used as industry's fuel. The trend is forecast to continue in the distant future as well.

Kinds of Oil	1993 - 1994	1997 - 1998	2002 -2003
HOBC + MS	8%	9%	10%
SK + JP - 1	25%	23%	23%
HSD + LDO	49%	53%	53%
JBO + HSFO	12%	8%	9%
Others	8%	6%	5%

HOBC High Octane Blending Component,
MS : Motor Spirit
SK : Superior Kerosene Oil
JP I : Jet Propulsion - I
HSD : High Speed Diesel
LDO Light Diesel Oil
JBO Jute Batching Oil
HSFO : High Sulfur Furnace Oil

5.7.2 Oil **Distribution in Bangladesh**

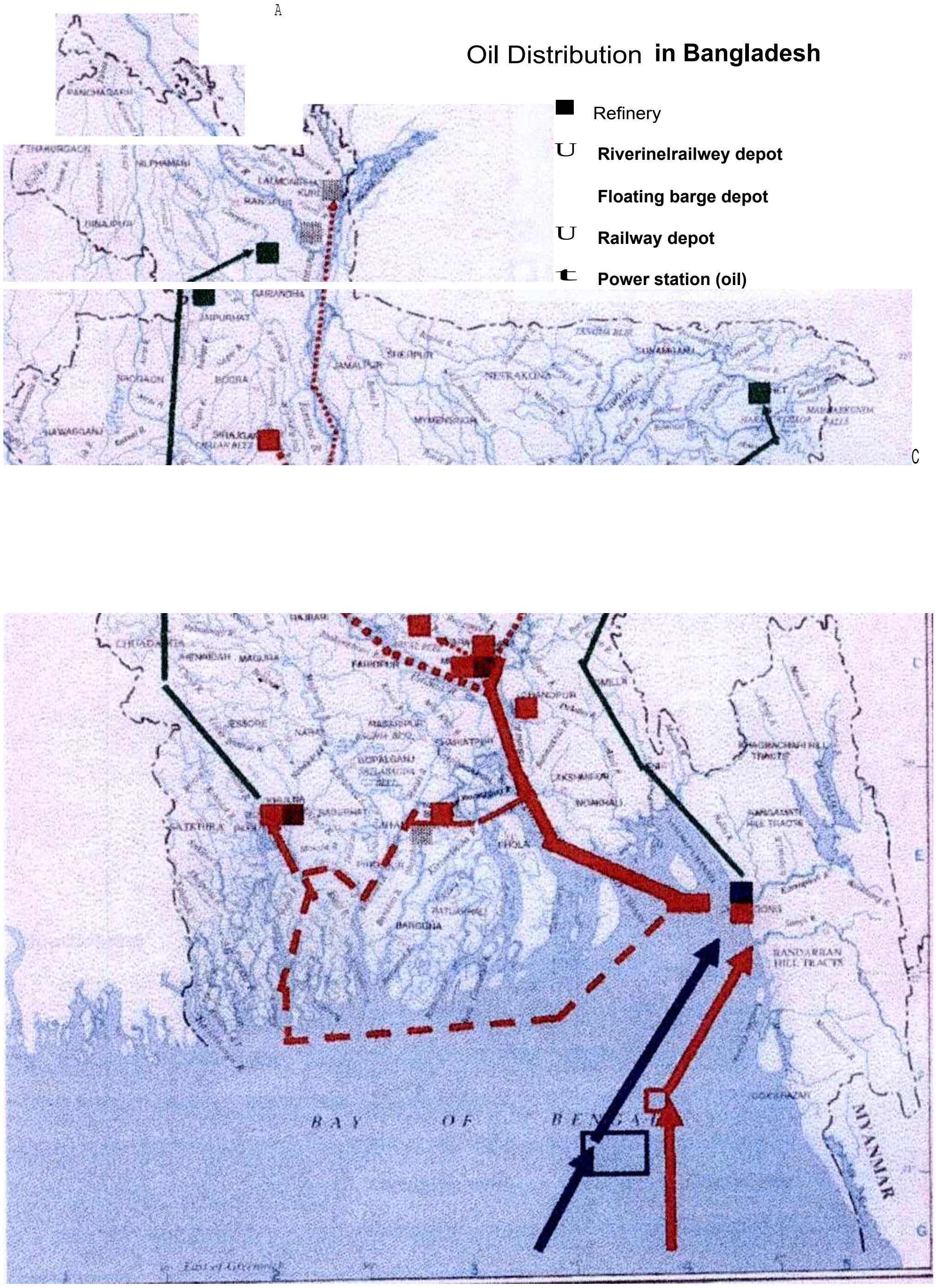
Oil distributions in Bangladesh have been investigated. There is only one oil refinery called Eastern Refinery Limited in Chittagong and there are 40 oil marketing depots in locations. These are main installations, riverine railway depots, oil barge depots and railway depots. There are two power companies which are using oil as fuel. Thanks, to availability of natural gas, which is being used by other power companies.

About 3.5 million ton of crude oil per year is imported from Middle Last counties by 200,000 DWT tankers, and discharged from mother tanker at Kutubdia anchorage about 60 miles south - west from Chittagong port and loaded on shuttle/lighterage tankers and then transferred to refinery.

Apart from that, Main installations in Chittagong receive not only refined products from refinery, but also receive another about 3.5 million ton per year as imported petroleum products. Thus about 7.0 million ton petroleum products per year are distributed by mainly coastal tanker and railways. Lorry (tanker bowser) is not main distributor, but its carriage is increasing.

Movement of petroleum products by waterways to different oil depots is shown as follows:

Supply source	station (Oil depot)	Quantity (.i'h)	or total nioemcut
Chittagong	Godnail	1,7c0,0011	
Chittagong	Fathdla	1,4()0,000	20
Chittagong	Daulayxu	1,4()0.000	20
Fatulla, Godnail	Baghabari	1.0.10,000	I>
Chittagong	Chittagong	700.000	111
Chittagong	Barisal	281).000	
Chittagong	Chilmari	14() 000	
Chittagong and others	Othcrs	28().000	
		'l otal: 7.000.000	IUO



Source: Bangladesh petroleum Corporation

Petroleum Oil Distribution Network in Bangladesh

5.8 State of Marine **Pollutions** in Bangladesh

5.8.1 Identification of Probable Oil Spill Sources

Oil spill arises both from operational and accidental sources. Operational sources are loading/unloading, bunkering and other routine operations (e.g. deballasting and debilging). Accidental sources are tank rupture, ship collisions, grounding and hull failures. Other oil spill sources are there due to ship breaking operations.
With the information gathered. a map has been prepared which **shows potential oil spill areas of the waterways of the country.**

Firstly, the existence of oil handling facilities facing **the waterways (e.g. refinery, oil depots and oil using by power generation companies), is quite often responsible for both operational and accidental causes of oil spill.**

Secondly, the tanker distribution route. Specially anchoring and deballasting debilging areas (operational causes), may also subscribe to oil spillage, at times, besides collision at crowded traffic area and grounding at navigationally dangerous points are also no less contributors to the oil spill (accidental causes).

Thirdly, ship breaking area near Chittagong along the coast line (operational cause) is considered to be highly prone to oil spill.

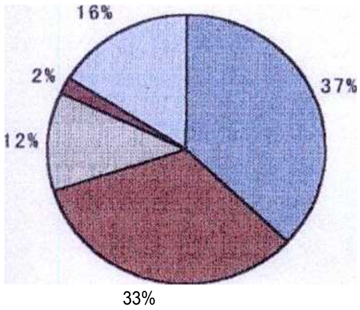
The Department of Environment (DOE) has identified the pollution of the area with three pollution sources:

a) oil and chemical substances discharged from the industrial /,one in the north area.
b) Sewage discharged from the urban areas. and
c) Oil spill, deck drainage and garbage disposal from the ships in the mouth of the river and at the anchorage area.

Along the coast of the Chittagong a large ship breaking industry has been growing causing potential environment degradation. A large amount of engine oil along with the remaining fuel oil and other oily substances are washed away into the sea. Dumping of rotten foods and food items, expired medicines and/or other merchandise commercially not feasible to unload are also causing serious pollution in the hay.

According to US Academy of Science, Major inputs of petroleum to the marine environment to the extent of one-third emanate from land source (industrial discharge and urban run-off) and almost half from ships (vessel operations and oil tanker accidents)

Major inputs of petroleum to marine **environment**



0 Industrial discharge and
urban run-off
Vessel operations

O Tanker accidents

■ exploration/production

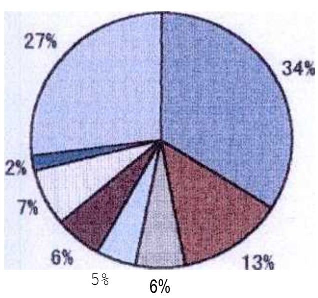
❑ others

Source: **Bangladesh Petroleum** Corporation

It is, therefore, important to recognize the necessity of preventing oil spill not only from ships but also from land sources.

According **to statistical data by** ITOPF (**International Tanker Owners Pollution Federation Limited), Major causes** of Oil Spill during 1974 **to 1998 can be attributed to loading/discharging**, **bunkering and other routine operations**, **about 53%, and to collisions, grounding and hull failure about 19%.**

Major causes (oil spills 1974-98)



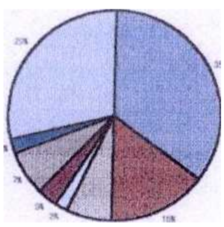
m Loading/discharging
Mother routine operation
O bunkering
O collisions
■ grounding
0 hull failure
Mfire and explosion
❑ others

Source: Bangladesh Petroleum Corporation

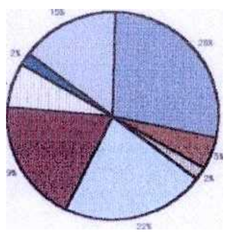
Now, if we divide these data by spill size, by (i) small spill 7 ton below, (ii) medium spill from 7 to 700 ton and (iii) large spill 700 ton above, we will observe that there are quite many small spills which are mainly caused by operational incidents and like loading/discharging, bunkering and other routine operations, and account for almost 60%. On the other hand, large spills are few and far between, but the spilled volume is very large and the causes are mainly tanker accidents (those are collisions, grounding and hull failure, and account for 75%). And medium spill features are as shown between the middle of those small and large spills.

5.8.2 Oil **Spill Incidents in Bangladesh**

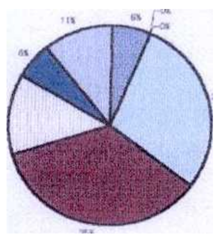
Spill < 7 ton



Spill 7 - 700 ton



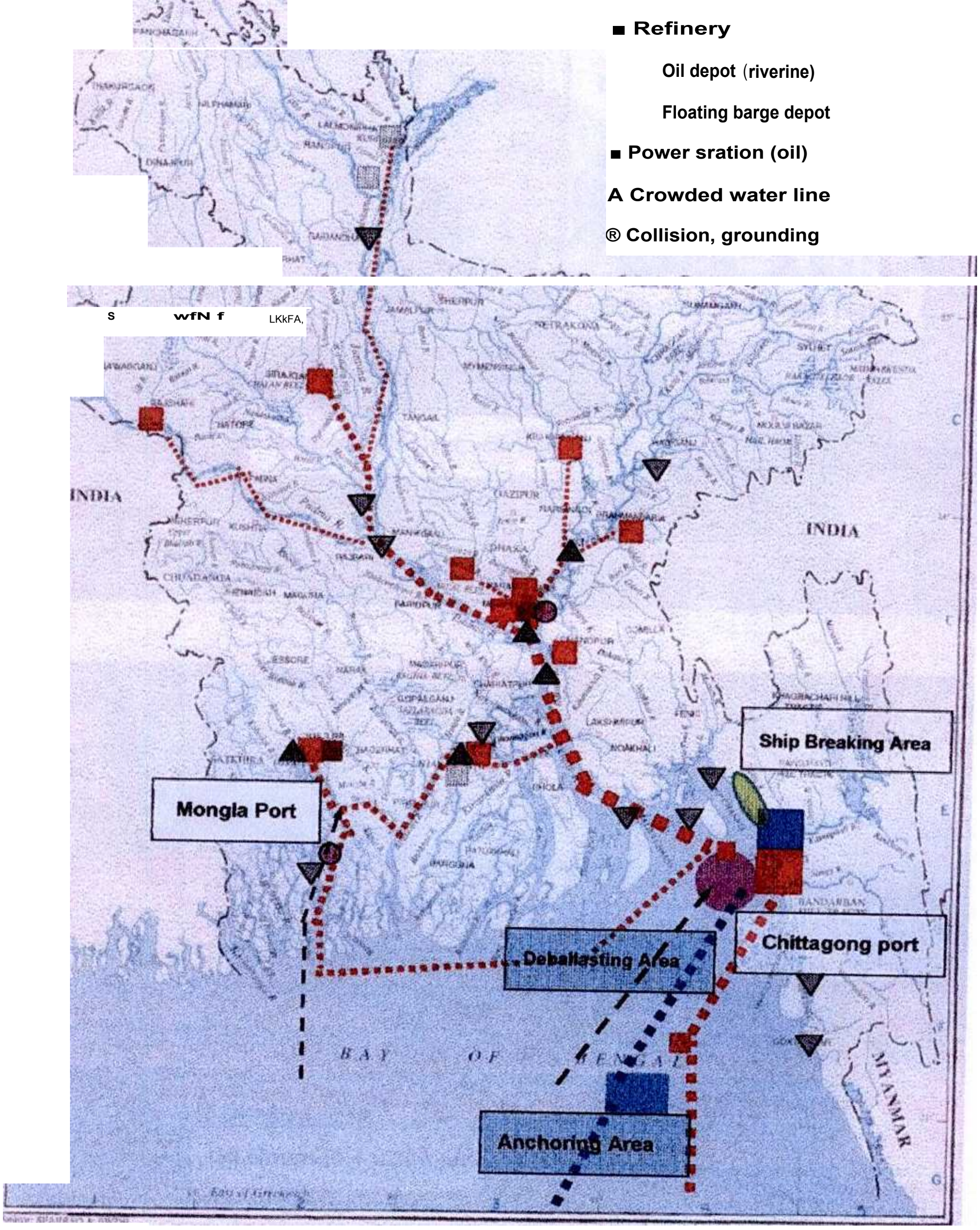
Spill > 700 ton & above



Source: Bangladesh Petroleum Corporation

Oil spill incident reports have been collected from MPA, CPA, DOE, DOS and also surveyed published book (State of environment report 1999/PP-64; edited by Muamnul Islam Chowdhury, a publication of the Forum of Environmental Journalists, Bangladesh). The results though not very recent, but provides history and trend results as tabulated below:

	UA , faLar.			
	Coast			
1992	Khulna Coast			
1994	**Mongla**	**Pavlina**	Bunker oil	Loading,
			191,	**Routine**
				Operation
1995	**Khulna**		.1130 , FO	Loading,
			10	**Routine**
				Operation
1999	Offshore of	Ocean Wave	13unkcr Oil	Loading,
	Hiron-Point		352	Routine
				Operation
2001	**Khulna**	**Kalindi**	Diesel Oil	Loading,
			230	**Routine**
				Operation



Source: Bangladesh Petroleum Corporation

Oil Spillage Area **in Bangladesh**

Nvuu.. iii I uaau [[V C[, iapall I)[I I'.llelliCC I'111g I o.. I Ad.,
Japan in association with Fuyo **Ocean Development** & Engineering Co., Ltd., Japan **conducted a detail survey and use of a standard simulation** model which revealed following **findings:**

5.9.1 Methodology of Analysis

The applied risk analysis method is based on ISO 11000 series that is international standard for environment system provided by International Organization for Standardization (ISO). In this analysis, risk means possibility or chance of facing danger, suffering, loss or injury.

Formula of risk analysis is as follows:

Risk result OO = Frequency (F) x Seriousness of the result

Where Frequency (F) = Possibility of occurrence (A) I Possibility of detection (13)

Hence, R = (A+B) x C

And the rating of A, B and C is as follows:

A		B		C	
Possibility of occurrence		Possibility of detection		Seriousness of the result	
(standard of rating I - 5)		(standard of rating I - 5)		(standard of-rating 2	10)
Extremely high =	5	Extremely low	5	Very high	= 10
High =	4	Low	4	Iigh	8
Moderate =	3	Moderate	3	Moderate	6
Low =	2	High	2	Low	= 4
I xtremely low =	1	Extremely high	I	Negligible	-2

Note 1: Possibility of detection (B) includes not only the detection but also actions after detection.

Note 2: Seriousness of the result not only considers the scale and continuation of influence, but also mitigating technology and its costs.

because of getting no permission from authority. But Mongla Khulna area (Pussur river lane), Narayanganj and partly Chittagong other area have been analyzed by the Consultants. The results have been stated below. The higher means the score of rating. The higher is the risk of oil spill. In other words. This score means the priority requirement of countermeasures. Thus, this will provide the necessary data base for planning to prevent oil spill.

Occurrence oint (location)	**Preventing** Facility	**Frequen** CN (A+ B)	Seriousness (C)	Rating (R)
Crude Jetty (Chittagong)		2+4	10	60
Oil Jetty (M-1) (Chittagong)		4+4	8	64
Oil Depot (Khulna)	(dike)	4+4	8	64
Oil Depot (Nara y angan')	(dike)	3+4	8	56
Power company Khulna	Dike, boom	2+2	4	16
Mooring (M-4) (Mon Ia Port)		3+5		64
Inland waterways Khulna		4+5	6	54
Ship breaking area Chitta Tone		5+4	8	72

In this table, the score **of Khulna Power Plant** Company is very low, because they **possess not only necessary preventive** facilities, **but also** emergency **plan and** necessary response equipment to promptly cope with the impact of oil spill.

Chittagong is the principal port, handling 85% of imports and 80% of- exports of the country. It is situated in the estuary of the Karnaphuli River. The significance of this **port is that it provides a deep-water anchorage** a few **miles inland from the Bay of Bengal. The port comprises container terminals, multipurpose berths. general cargo terminals, exclusive terminals to handle break-hulk cargo**. hulk cargo **terminals to handle clinker, fertilizer and exclusive oil terminals to handle crude oil and petroleum products. The available data shows that at present about 5 million tons of crude oil is** i**mported by the country at pace of approx**. 10 % growth which **are transported by** VLCC (Very Large **Crude Carrier).**

5.10.2 Chittagong Port Scenario

The 170 km long Karnaphuli, a major river of the region, falls into the Bay of Bengal through Chittagong. Wastes discharged fro numerous industries located on its banks. land based wastes from urban areas and residues of agro-chemicals pour non stop into the river in huge quantities. Oil spilled from ships and inland boats also cause pollution. Ship breaking yards as well causing pollution due to wastes from scrapped ships including oil. Untreated industrial organic effluents including heavy metals, ammonia pose threats to total chain of ecosystem and f ishcries.

Crude oil is spilled into the water during transportation and handling from nearly 1500 coastal tankers, about 600 foreign tankers. 2600 mechanlzed boats, and dockyards etc., cause pollution.

Chittagong has the country's only oil refinery located at the estuary of Karnaphuli River. With about 5.0 million tons of crude oil and finished products imported and carried by tankers up to 250,000 deadweight tons. Since due to their size and draught restriction, are not able to enter the relatively shallow port. Consequently, transshipment is frequently carried out using smaller ships that shuttle between the outer anchorage and the oil terminal berths on the Karnaphuli River. After refining, oil products including imports are distributed by inland water transport vessels of size as fuel by domestic general cargo vessels and international general and container cargo vessels, which operate in the main rivers and coastal ports respectively.

5.11 Mongla Port

5.11.1 General Feature

The port of Mongla is situated 85 km inland from the Pussur River entrance which Faces a dynamic erosion and sedimentation profile. Cargo is almost entirely handled directly between oceangoing vessels and inland river craft at the port's river moorings, which have deeper water than alongside the port's berths.

The port has trade links with most of the ►najor ports of the world, although vessels arriving there are mostly from ports in Asia. Mongla has lost a large part of its dynamics compared with Chittagong, largely as a result of its physical constraints, backward integration including poor land and maritime accessibility. In the last 10 years, Mongla has lost half of its market share to Chittagong, and now handles about 15% of country's seaborne trade.

5.11.2 Mongla Port and Sundarban Forest Scenario

Mongla Port is situated only 3 km north of the Sundarbans Reserved Forests (SRF), declared as World Heritage Site by UNESCO. Critically enough, Mongla Port is reached mainly by a 100 km long navigational channel through Pussur-Sihsa River system that runs through the SRF. Mongla Port, second port of the country. has lower risks of oil spills than Chittagong port owing to the less traffic and absence of oil refinery. However, the refined oil products including imports are distributed by inland water transport vessels of size up to 1000 DW'I' to oil storage depots at various inland river ports and terminals passing through the coast from east to west and enter into the inland waterways through the river system of the Sundarban Forest, which cause threats oil spills out of operation and accidents.

Mangroves. marshes, fishes and shrimps were considerably affected.

As for the ships other than tanker, Bangladesh has more than 5,000 registered ships which include more than 500 ships above 400 GRI. These ships are also almost aged and have been in use for long years , and do not have any oil discharge monitoring and control system with oil filtering equipment as prescribed in MARI'OI, 73/78. Apart from these, thousands of' engine boats have been plying in Bangladesh waterways including port areas which are still to be brought under legal obligation and these no doubt, constitute additional threat of pollution.

5.12 Chittagong and Mongla Coasts - Vulnerability to Oil Spillage

The Chittagong and Mongla ports are becoming increasingly vulnerable to oil spillage and a consequent ecological disaster due to an increasing number of maritime traffic bringing in 3.5 million tons of oil annually. Although direct spill risks are more at Chittagong port and Mongla also appears increasingly exposed to such threat. Over 200,000 tons of- oil is carried annually as fuel in vessels operating, through Mongla shipping lane.

It is said that Bangladesh has not been able to do much work to tackle any such disaster till now at the national level. Due to various constraints, the country has been rather slow to adopt relevant international conventions aimed at mitigating such oil spillage impacts.

Oil is one of the vital growth propellers, but it could be risky as well when spillage occurs due to collision, running aground of' vessels due to engine failures, navigational errors, rough weather conditions or dragging of anchors specially in and around the port areas. With the Sundarbans Reserve forests only three kilometers away from Mongla port, the necessity of preparing a cost-effective response management programme depending as much as possible on easily available local inputs and local know-how.

Most spills involve deliberate or careless flushing of oily residues from ship and port installations, or occur during refueling and oil handling in ports. The other major concern is due to accidental oil spillage from ships carrying crude oil as bulk cargo. Risks of direct oil spill at Mongla Port are lower owing to small traffic volumes and absence of oil refinery where hulk crude is delivered on regular basis. Mongla Port being 3 km north of the Sundarbans Reserved Forest, which was declared a World Heritage Site. Without proper management, monitoring and risk assessment, the movement of oil and chemical products is a potential major threat fir the area.

_5.14 Current Status of Preparedness and Mitigation and Response Strategies

Bangladesh has no public oil residues reception facilities as prescribed in MARPOL 73/78. **and only has a private company's reception facilities Ibr I:RI, and a power station**. **The installing proper reception** facility at Chittagong **port is still to see the light of the day, although some make shift arrangements** are reportedly **there and their services are mainly availed** by privately **engaged contractors**. The port **and terminals do not still have any plan to install the reception** facility.

Keeping in mind the work so far done by South Asia Co-operative **Environment Program** (SACEP) **and International Maritime Organization** (I MO). in the licld of oil **spill response management** strategy, **a draft National** Oil Spill Response **System along with related** Contingency **Plan has been prepared**. The System **and plan may be considered as compliance** to only of **the efforts** made by SACI;P for a viable **Response Management Program and those** of IMO covenants including OPRC **(International** Convention **on Oil Pollution Preparedness, Response and Co-operation, 1990) Convention on the subject.**

The updating and finalizing project of the South Asian Seas Oil Spill Contingency Plan (2001-2002) has secured funding support from UNEP and IMO for a joint IMO SACEP project. The participating countries of this project are Bangladesh, India, Maldives, Pakistan and Silence. In the High Level meeting held in 2000 at Colombo.

As regards to national Oil Spill Contingency Plan. department of Shipping, Govt. of Bangladesh has prepared a draft National Marine Pollution Contingency Plan. presumably with an image of large oil spills along the coastal area. The draft plan though has not clearly prescribed the required items of assistance from the Regional Contingency Plan, but speaks of geographical coverage applicable to pollution, level of emergency and also response strategy, in addition to particularly sensitive areas. It is accordingly to be assumed that the draft National Contingency Plan will he revised and coordinated with the regional plan to ensure an efficient response program.

However, at the end, Bangladesh present scenario is as under:

- There is no National Oil Spill Response System.
- there is a little response equipment and material.
- 'T'here is no appropriate reception facility.
- SACEP (South Asia Co-operative F,nvironment Pro(Iram) is now under process
- There is limited safety regulation and control on waterways and in respect of marine operations.

The effect of oil spills can be far reaching, posing both an environmental and economic threat. Recreational activities, local industry, fisheries. and marine life are among the resources that can be adversely affected by oil spills. Since no major incident of oil spill have yet occurred in Bangladesh water, examples of major such incidents which occurred at different places worldwide. their salient features with emphasis to reason of incident occurrence, impacts of environment and economy and response and recovery measured adopted have been described below for understanding of the subject for taking mitigation and preparedness measures to face and counter such disaster in Bangladesh and in regional waters.

6.1.1 Environmental Impact

The exact nature and duration of any impacts from an oil spill depend on a number of factors. These include the type and amount of oil and its behaviour once spilled; the physical characteristics of the affected area; weather conditions and season; the type and effectiveness of the clean-up response; the biological and economic characteristics of the area and their sensitivity to oil pollution.

The importance of plankton in primary productivity of'the oceans and as a temporary home for the eggs and larvae of' fish, shellfish, sea bed and shoreline organisms is well known, but there is evidence of widespread harm to these functions from spills which subsequently translates into long term danmage.

Seabirds are amongst the most vulnerable inhabitants of open waters since they are easily harmed by **floating oil. Species that** dive Im their food from the **sea surface are particularly at risk**. The most **common** cause of death is from drowning, **starvation and loss** of'body heat following fouling of plumage by oil.

Shorelines, more than any other part of the marine environment, are exposed to the effects of oil as this is where it naturally tends to accumulate. I Iowever, many of the animals and plants on the shore are inherently tough since they must be able to

In tropical regions, mangrove swamps replace salt marshes and provide an extremely rich and diverse habitat as well as coastal protection and important nursery areas. The mangrove trees which provide the framework upon which this habitat depends can sometimes be killed depending on the type of oil and the substrate in which the trees are growing. Damage is more likely if oil smothers their breathing roots or if toxic oils penetrate the sediments. Where high mortality of trees occurs, in some cases including trees which are 50 or more years old, natural recovery to a diverse and productive structure can take decades. An important function of both salt marsh and mangrove habitats is that they provide organic inputs to coastal waters which in turn enrich the communities living there. It is in these marsh and mangrove areas where damage has been recorded that reinstatement measures have real potential to speed up recovery.

A salt marsh impacted by an oil spill before (left) and after (right) replanting

Mangrove Area impacted by an oil spill

Source: The International Tanker Owners Pollution Federation Limited (ITOPF) related sports. Tourism with Hotel and restaurant owners and others who gain their livelihood from the tourist trade can also suffer temporary losses. A return to normal requires an effective clean up programme and the restoration of public confidence.

Beach-shore impacted by Oil Spill

Source: **The International Tanker Owners Pollution Federation Limited** (ITOPF)

A common cause of economic loss to fishermen is interruption to their activities by the presence of oil **or the performance of clean-up operations**. **Sometimes this results from a precautionary ban on the catching and sale of fish and shellfish from the area, both to maintain market confidence and to protect fishing gear and catches from** contamination.

Industries that rely on seawater for their normal operation can also be adversely affected by oil spills. Power stations and desalination plants which draw large quantities of seawater can be particularly at risk, especially if their water intakes are located close to the sea surface, thereby increasing the possibility of drawing in floating oil. The normal operations of other coastal industries, such as shipyards, ports and harbours, can also be disrupted by oil spills and clean-up operations.

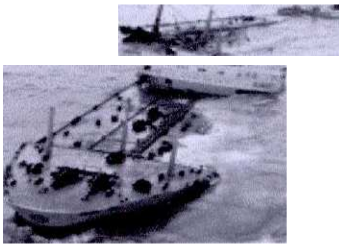
affected area; time of year and weather conditions, and notably the clean-up and response strategy used. Recovery is usually a well conducted clean-up operation but in some specific habitats aggressive clean-up methods can cause more harm than good and then it is better to let natural cleaning processes take their course.

6.1.4 Accidental Oil Spillage and Impacts at Recent Times

Photographs' Source: The International Tanker Owners Pollution Federation Limited (ITOPF)

Following are the few examples of incidents of oil spillage from ships and their subsequent response and rescue operations to reduce and minimize damages and impacts and recovery measures to bring the affected areas to normalcy.

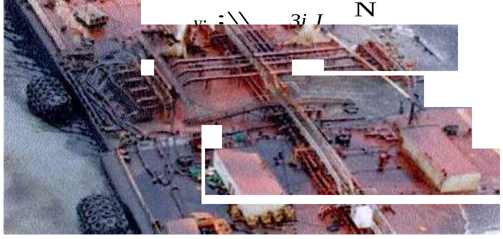
Oil Spillage from Tanker `Torrey Canyon'



Source: The International Tanker Owners Pollution Federation Limited (ITOPF)

Tanker TORREY CANYON ran aground on Pollard Rock on the Seven Stones Reef, near Lands End, Cornwall on 18 March 1967. Thousands of tons of oil were soon spilling from the stricken vessel's ruptured tanks and during the next 12 days the entire cargo of approximately 119,000 tons of Kuwait crude oil was lost.

The escaping oil polluted many parts of the south west of England, causing the deaths of thousands of seabirds and threatening the livelihoods of many local people in the tourist season.



Source: **The International Tanker Owners Pollution Federation Limited** (ITOPF)

The Maltese tanker TASMAN SPIRIT (87,584 DWT) **grounded at the entrance to Karachi Port, Pakistan in 2003**. **The vessel was carrying 67,800 tons of Iranian Light crude oil destined for the national** refinery **in Karachi. In total, it is estimated that some 30,000 tons of oil was spilled** from the TASMAN SPIRIT.

Much of the spilled oil quickly stranded on Clifton Beach, the main tourist beach in Karachi. Due to quick response further impact of the disaster could be reduced resulting in little or no impact on mangroves, salt pans and other sensitive resources in the vicinity. The geographical extent of shoreline oiling was limited to a ten-mile radius around the grounded tanker. However, there were few reports of repercussions of the oil on fisheries; a three-month fishing ban was imposed by the Marine Fisheries Department along the coastline directly affected by oil, extending five nautical miles offshore.

Oil Spillage from Tanker `Tanio'

Source: The International Tanker Owners Pollution Federation Limited (ITOPF)

On 7 March 1980 TANIO, carrying 26 000 tons of No. 6 fuel oil, broke in two during violent weather conditions off the coast of Brittany, France. As a result approximately 13,500 tons of cargo oil was spilled. The spilled oil began to be washed ashore and eventually contaminated about 200 km of coastline to varying degrees. Many of the worst affected areas could not be boomed effectively because of the nature of the coastline, the extremely large tidal range (9m) and the severity of the weather at the time of the accident.

Tourism was of major importance in Brittany. However, the impact restricted the beach to return to its normal life before a little more tan a year time.

Oil Spillage from Tanker `Erika'

Source: **The International Tanker Owners Pollution Federation Limited** (ITOPF)

The Maltese tanker ERIKA, carrying some 31,000 tons of heavy fuel oil as cargo, broke in two in a severe storm in the Bay of Biscay on 1 1 December 1999, 60 miles from the coast of Brittany. About 20,000 tons of oil was spilled.

The main environmental impact of the spill was on sea birds. Almost 65,000 oiled birds were collected from beaches, of which almost 50,000 were dead. A major cleaning operation was mounted for the 15,000 oiled survivors and 2,000 were ultimately released.

The magnitude of the spill and the length of coastline affected resulted in a large number of compensation **claims**. Important coastal fisheries, mariculture (oysters and mussels) and tourism resources throughout southern Brittany and the Vendde were severely affected.

Photographs of similar Disasters:

The below shown photographs are only few of hundreds which clearly show some of the impacts of the disasters.

AMOCO CADIZ (**France, 1978)**

Source: The International Tanker Owners Pollution Federation Limited (ITOPF)

PRESTIGE (Spain, 2002)

Source: The International Tanker Owners Pollution Federation Limited (ITOPF)

SEA EMPRESS (**United Kingdom, 1996)**

Source: The International Tanker Owners Pollution Federation Limited (ITOPF)

A Beach after an Oil Spill

Source: **The International** Tanker Owners **Pollution Federation** Limited (ITOPF)

Volunteers **engaged in Beach Cleaning**

Source: The International Tanker Owners Pollution Federation Limited (ITOPF)

Duck covered in **oil as** a result of The 2007 San Francisco Bay Oil Spill

Source: The International Tanker Owners Pollution Federation Limited (ITOPF)

Chapter 7: Modeling, Risk Assessment and Monitoring

7.1 Forewords on Risk Assessment and Monitoring

Petroleum products that enter the marine environment have distinct effects. according to their composition, concentration and the elements in the environment that are taken into consideration. Some effects can be related to transformations of the chemical composition of the environment and alterations in its physical properties, the destruction of the nutritional capital of the marine biomass, danger to human health, and changes in the environmental biological equilibrium.

Numerical models are intrinsically able to predict the evolution and behavior of oil spilled at sea, regardless of the atmospheric conditions. hence the vast interest in them. Mathematical modeling is thus a very powerful tool for management assessment after an oil spill accident, particularly for determining preventive measures and to help monitoring accident evolution.

The latest information technologies have provided us with new tools and different strategies in the field of environmental management that are capable of efficiently processing the great quantity of information needed to support accidental hydrocarbon spill management.

These **modeling tools are** now of paramount interest in the forecasting of oil slick **evolution at sea. as they allow measures** to mitigate the negative impacts associated with hydrocarbon spills to **be put in place**. When integrated into Geographical Information Systems tools, **the information** yielded by the models' simulations can be analyzed easily **and appropriately.**

7.1.1 Environmental Impacts of the Spills

The petroleum products that enter the marine environment have distinct effects, **according to their physical and chemical composition**. **and the environmental elements**

that are considered. The mechanisms of toxic action depend on the petroleum's characteristics. The toxicity of the various fractions of the pollutants is directly related to the distilled products, on a short-term basis, and related to the slow-action products, on a long-term basis. It is also related secondarily to the products degraded either biologically, through the action of bacteria, or through physical-chemical processes. Petroleum pollution can be detected through the modification of the environmental conditions and can be described by:

- transformations of the chemical composition of' the environment and alterations in its physical properties;
- **destruction** of the **biomass' nutritional** budget:
- changes in the environmental biological equilibrium.

From the physical point of view, **hydrocarbons** directly **influence the marine environment**, **since gas transfer mechanisms are disturbed** by the **presence of a pollutant layer on the surface**. **Self-purification processes arc thus reduced. "These processes can he aggravated by the increased oxygen consumption** by ;growing **micro-organisms, depending on the quantity of biodegradable organic matter present**. This oxygen deficit **could even create conditions for anaerobic** life, giving rise to the death **and disappearance of certain species and permitting the fermentation of organic residues.**

From a biological point of view, the environmental effects of oil are varied and complex. While some are immediately obvious, others only manifest themselves after a long period. The degree of the effect is therefore different, whether in the animal or in the plant kingdom. In the case of' crude oil, the volatile components and the aromatic compounds are the most toxic.

In addition to possible direct intoxication resulting from the inhalation or ingestion of petroleum products, there is an indirect risk to humans from the consumption of certain marine animals (fish, crustaceans, shellfish, etc.) that have been in close contact with the oil.

The pollution's noxious effects can also be felt indirectly through its environmental and economic impacts: damage to biological resources (flora and fauna), affecting biodiversity; deterioration in seawater and shoreline quality, \yith negative effects on economic activities.

The first and hardest influences to gauge are those that take a broader view of the oceans as one of humanity's last resources. In a narrower sense, it is important to keep in mind that an oil spill affects all the people who directly or indirectly exploit marine resources. particularly those related to tourism, fishing and fish farming.

7.1.2 Oil **Spill Detection and Control**

In order to efficiently combat the permanent danger of marine pollution caused by hydrocarbon spills, it is extremely important, once a spill has been detected. to be able to predict both the discharge location and the transformations that the hydrocarbons undergo in time, quickly and precisely.

Tele-detection is a widely-used technique employed with considerable success to define the affected zones, to determine the extent of the spill and to help the ships combat pollution. For that purpose, aerial detection sensors have been developed. However. under adverse meteorological conditions, they only provide sufficient information when used in combination.

Under favorable conditions, the tole-detection technique is capable of defining the zones affected and the extent of the spills. It could even help guidance for ships combating pollution. Tele-detection data could also serve as entry data to verify the results obtained from provisional models of spill evolution. However, this technique is difficult to use in unfavorable atmospheric conditions, which are the most likely ones to prevail during accidents at sea.

Containing operations at sea generally involve the use of floating harriers that can he used to confine, concentrate or manage oil slicks. Various types of collection equipment may he used, the choice of which will depend on the following factors: spill location and dimension, movement of the spill, meteorological conditions, hydrographic conditions, and protection priorities.

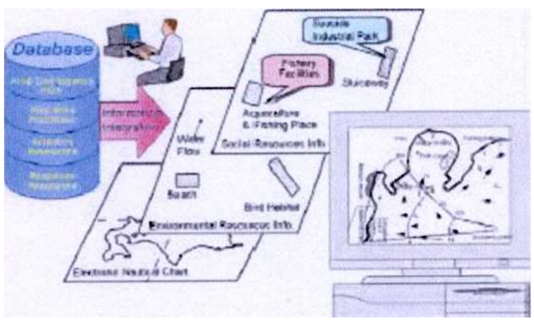
The elimination of surface hydrocarbons is one of' the main goals of pollution-control actions and various methods have been tried to tackle the problem. The physical removal of the oil is generally considered preferable to chemical removal, since it does not introduce additional substances into the marine environment, involves a smaller quantity of irrevocably lost hydrocarbons and permits the reuse ofthe collected products.

7.2 Concept and Integration of Models and Geographic Database for Risk Assessment in Coastal Area

7.2.1 Geographic Database

Ship navigation and operation in Port Areas is difficult due to port's own characteristics such as geomorphology, structures, weather and so on. Because of various factors, it is complex to assess maritime traffic safety in the port. In addition, some new structures are built in the port and it may be sometimes a risk factor in coastal area. Before construction work, its safety should be validated. Other risk factor in coastal area is a pollution accident. Coastal environment is very dynamic and influenced by various elements. There are many marine models to calculate the features of marine environment but most their results are represented by static graphs or simple static images. In order to protect the environment from the pollutant spill, spatial spill should he preceded in response of the pollution accident. Simulation experiment is a good method to ensure safety and assess risk. Simulation database consist various geographic datasets and requires data integration. And the database should represent the real coastal area and have scientific accuracy. There is no standardized coastal data infrastructure. 'T'here are many kinds of geographic datasets to implement the coastal area. These are made in different organizations with different purposes. So, there are diverse formats. scales, making time and method. In order to integrate these datasets for the simulation. these datasets are converted, combined or extracted with some methods. And new datasets are sometimes created from them. Obtaining data sources and processing scheme are necessary to build spatial database efficiently. In this study, nautical charts, digital maps, satellite images and etc. are used to build spatial database. Information for assessing risk in coastal area is extracted from them and sometimes combined with other marine models or marine virtual reality. It has combined some models and applied to simulation program for assessing risk. This database is validated through a lot of simulation experiments. This study introduces efficient and economical procedures for building database. And it reviews the limitation of building database using current datasets and methods. This study is very meaningful for building and managing geographic database for coastal safety assessment. It may change a paradigm of marine spatial datasets. Through the studies or tryouts like this, marine spatial data infrastructure could be standardized and advanced.

Pollution Spill Simulation System: In order to respond to any pollution accident, information on the potential risk, weather of sea area and the sensitivity of coastal zone to pollutant spills are required. Through the spill simulation of the pollutant, decision making for efficient response is possible. For simulating of the pollution situation, pollutant spill model and weather prediction model should be necessary. These mathematical models should be integrated into GIS database for interactive display, query and analysis by emergency response planners. Simulation based on GIS can be a powerful integrating technology for emergency responders during actual pollutant spills or virtual preparedness drills.



Pollution spill simulation component

To estimate risk of the pollutant spill effectively, understanding the environmental sensitivity of shoreline is required. The ESI shoreline classification represents an index of relative exposure to shoreline slope, wave and tidal energy, biological productivity and sensitivity. As ENC (Electronic Nautical Chart) dataset has no F S1 (I,nvironmental Sensitivity Index) information, environmental sensitivities of shoreline should be surveyed in the field. In case of impossible surveying. they were obtained through the aerial photo images. In risk assessment, the information about response resources around the accident area is important.

7.2.2 Integrating Database and Marine Model

This system has used numerical models to calculate sea area Feature and pollutant spill. These models provides the sea surface temperature, air temperature. sea depth. the speed and direction of wind, current, tide and wind driven current with the application. This application for integrating GIS and these models has been developed Visual C i i and FORTRAN. If the application recognizes the location and date of the accident, the pollutant spread could be simulated and time series changes and risk map can be created.

7.2.3 Outline of the Study Model

In this study paper, critical discussion on available different mathematical models and their various uses have been made. Unavailability of any software here of any model in use in developed countries did not permit to carryout case specific study in this paper. However, this study paper has endeavoured to detail and elaborate with examples and in parallel picturing available models in use to understand the core issues of the purity and quality of data and parameters to be considered for integration with the models and related software for obtaining realistic results for the Risk Assessment.

In this Study Paper, one case of use of Models, selection of parameters, process of data input and flow of inputs and obtaining of results for desired Risk Assessment for a particular geographical location have been made.

The Project Area **in this case** has been focused on the area from Khulna to Hiron Point through the Mongla Port.

The scope of work is as follows:

- Environmental Survey in Sundarbans Forest and Water I';nvironment in Pusur River Area
- Preparation of Sensitivity Map
- Oil Spill Modeling
- Monitoring Planning

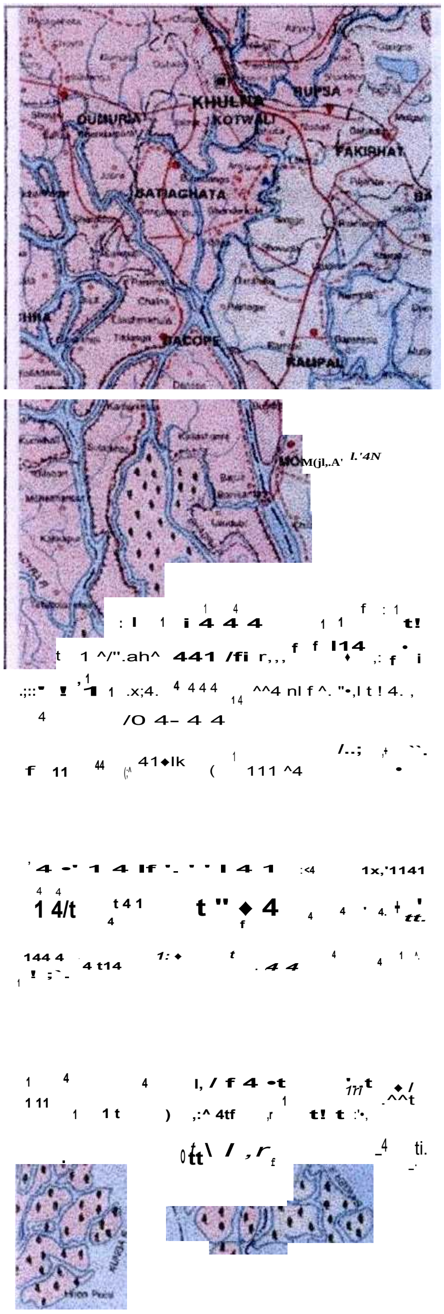
In the first stage. the Characteristics concerning the Water Environment and the Forest of Sundarbans in the project **area** have been considered and understood from the available and collected information and site investigation.

Environmental Sensitivity Map was made based on these data. The Oil Spill **Model is constructed based on the obtained data**, **and the simulation study executed. The Monitoring Plan is prepared from the study results.** In this Study, **the study is shown in the following order.**

7.3 Project Area

The Project Area of the Modeling is shown in Fig *7.3,* **covering the Sundarban Mangrove Forest and the River routes stretching up to Khulna City, Mongla Port and the adjoining areas.**

The north side Khulna city and the adjoining region cover dense populations of over crowded ground, the industrial areas, and the medium-small harbors all around the project area. The area from there to Mongla is an agricultural none where some small towns also exist. Mongla is the second largest Port in Bangladesh with large population who work in the port facilities. In the south of' Mongla area continues the vastness of mangrove forest of the Sundarbans stretching unto the Bay of Bengal.



Khulna Area (City with Large Population)
Factories, Human Habitat
Agricultural Field etc.

Chaina Area (**Middle**-size Town)

Agricultural Field
Cement Factory etc.

Mongla Area (Large Scale Port With Middle-size Town)
SUNDARBANS FOREST

Monkey Point

Akram Point
(The Junction **of Pussur and Sibsha River)**

Hiron Point

Fig 7.3: **Project – Study Area**

7.3.1 Outline of the Sundarbans Reserved Forest

The Sundarbans is the world's largest single tract of mangrove forest. located in the south west corner of Bangladesh (Latitude 21 deg 30 min and 22 deg 30 min N. and Longitude 89 deg and 90 deg E). The Sundarbans Reserved Forest (SRI) covers 6,017 square kilometers. Major portion of the Sundarbans is inundated by seawater twice a day. With low salinity, the mangroves from a tall dense forest where valuable spices like Sundri (*Herilierafomes)* and Gewa *(Excoecaria agallocha)* are common.

7.3.1.1 Topography of the **Sundarbans**

The Sundarbans (both Bangladesh and Indian parts) from the southern part of Genetic delta between the liugli River on the west and the Meghna River on the cast. I Bangladesh, the west is demarcated by the Raimangal river. The area has a number of low lying swampy islands formed by the main distributaries of the Ganges. In the eastern section between the Baleshwar River and the Meghna River, cultivation and clearings extend up to sea-face. The central portions between the Baleshwar and the Raimangal rivers had reserved forest in the past which at present have decreased.

7.3.2 Environmental Features of Study Area

7.3.2.1 Climate

'file climate in SRF is humid tropical with a marked seasonality of between monsoon summer and dry cool winter. Wet season (June to September) brines heavy rains under influences of South-West winds with 75% of the annual total occurring in this period. Dry season (November to April) brings infrequent rainfall under influences of the North and Northeast dry air. The temperature of the dry season rises to above 35 deg C in April and May. The pre and post monsoon months of May and October have violent and short-duration thunderstorms and severe cyclonic storms generated in the Bay of Bengal.

7.3.2.2 Temperature

The monthly and annual average maximum and minimum temperature at Mongla Station from 1991 to 2000 shows that the mean monthly maximum temperature at Mongla Station varied between 25.2 34.6 deg C, whereas the mean monthly minimum temperature ranged from 14.0 - 26.5 deg C. Variation of both annual maximum and minimum temperature is of the negligible order: the former is 30.8 deg C. and the latter is 22.5 deg C.

7.3.2.3 Precipitation

The monthly and annual total rainfall in millimeter at Mongla Station from 1991 to 2000 shows that the mean annual rainfall varied between 1232mm and 241 Omni. The variation of monthly total rainfall is largest in September ranging from 133mm to 591 min. In December, there are nearly no rains at Mongla for the last 10 years. In absence of meteorological stations inside the SRF, these values should be taken as an approximation.

7.3.2.4 Humidity and Wind

The monthly and annual average humidity at Mongla Station (1991 to 2000) **shows that the annual average humidity in the region** is 81.3%. The years **of 1995 and 1996 had relatively low values of humidity. However**, **the monthly, the monthly average humidity is rather high throughout the year ranging from 7 3.8% in March to 89.0% in August. Records indicate that Mongla Station never experienced relative humidity below below 80% from May to October for the last 10 years.**

The monthly average wind speed has a peak in May. The wind **comes from South in March to September and North-Northwest in other months.**

7.3.2.5 Hydrology

The Sundarbans receive water from the tributaries of the great river. namely, the Ganges. The Pusur River passes through the Study area in the SRF. 'there is a seasonal variation of salinity and fresh water supply. The Study areas along the Pusur River belong to Oligohaline-Mesohaline zone. The water salinity doest not exceed P YO in the monsoon months and less than 2% in the dry season. The average depth of Pusur River is about I5m. The rivers and canals of northern and southern part are less than the central part of the Sundarbans. The tidal variation is about 3m on between low and high tides.

7.3.2.6 Water Salinity

Salinity in the SRF is highly dependent on the volumes of freshwater flows discharging from upstream. The arrival of high water at the coast generally coincides with the peak in daily salinity. Tidal amplitudes during spring tides are 2.5 to 3 times higher than during neap tides. The higher water levels cause greater volumes of saline water to enter the forest than during neap tides. Measurements at I liron and Kaikhali between August and February indicate that salinity increases almost linearly from the beginning of October. and continues until the start of the monsoon (FAO/UNDP. 1998).

7.3.2.7 Tidal Regime, Movement and Inundation frequency

Semi-diurnal tides with a tidal period of about 12 hours 25 minutes are predominant in the Bay of Bengal. The tidal range pf the Study area is approximately 3 to 4m between the lowest and highest tides (Bangladesh Tide "fables 2001). Mean Tidal level is 2.3 l Om, 1.829m and 1.70001 at Mongla, Sundrikota and Iliron Point along the Pusur River respectively. The tidal regime is larger at Mongla than at I liron Point and also shows seasonal variation. The lowest tide at Mongla is 030m in March while it is 1.37m in August (13I WTA, 2000).

Tidal inundation frequency is a critical factor is seasonally dry regions, particularly in terms of seasonal freshwater flow. The lowest level of high water during spring tide occurs in February. The mean water level of the rivers changes between wet and dry season due to the onset of the monsoon winds and the high discharge of freshwater. "Thus the water reaches the highest level during the wet season and lowest level in the dry season.

7.3.2.8 Current Velocity and **Direction**

The Pussur-Sibsa River system is much cross-connected. The tidal water flowing up the Pussur and Sibsa Rivers penetrates into small rivers and khals. Strong tidal cater induces net tidal circulation with a strong spring-neap variation between the two major rivers.

The net flow in Kazibacha **changes direction** going eastward during the dry season. There **is an interaction** between **strong upstream** tidal flows in the Sibsa River pushing after eastward **in connecting channels to the Pussur** River. 'T'his with the ebb tide some of this **water** moves **downstream in the Pusur** River. Simulation studies conducted at SWMC have shown that **the net discharge at Mongla is about** 2000m3/sec at the end 01'.11.11Y.

7.3.2.9 Flora **and Fauna**

A total 245 genera and 334 plat species were recorded in the Sundarbans by Prain (1903). The Bangladesh mangrove vegetation of the SRF differs greatly from other non-deltaic coastal mangrove forest and upland forest associations. I)ifferences in vegetation have been explained in terms of freshwater and low salinity influences in the North-F,ast and variations in drainage and siltation. There is a total of 425 species of wildlife in the Sundarbans. Of these, 49 species are mammals, 3I5 are birds, 53 are reptiles and there are 8 amphibians. It is reported that over 120 species of fishes are common.
The estuaries of the Sundarbans are very rich in plankton. Mahmood et al., (1987) recorded 23 species of ichthyoplankton belonging to 19 families in samples collected from the river estuaries.

The complex and varied vegetation structure of the area is evident along the sea face to the strikingly different ecology of the muddy river banks or the swampy islands. Plant communities' of the Sundarbans forest vary in three ecological zones on the basis of salinity.

The salinity is the most important ecological parameter in the Sundarbans and ultimately influences the distribution of vegetation. The internal heterogeneity of the plant community varies according to geomorphology and hydrology. Karim (1992) identified two distinct groups of plant species depending upon their position on the landform settings. The first group consists of Keora, Choyla. Garjan, Sada bacn, Khalshi, Golpatta and Porteresia coarctata and is restricted to the foreshore mudliats and to the outward inclined slope. The species of second group, namely Sundri, Gewa, Goran, Kankra, Passur, Dhundhul, Amur, Singra and Hantal, are hackswamp mangals that lie on the inland slope of the levee.

7.3.3 Oil Dispersion **Experiments**

The experiment of the Study work carried out by Japan Oil Ungineering Company Ltd., and Fuyo Ocean Development & Engineering Company Ltd. Under l'echnical Assistance of Asian Development Bank to Bangladesh Government was aimed to reduce and mitigate the oil spill impacts on the mangroves in the SUndarbans. Different species have different tolerance against various oil products. Therefore, a test of deliberate oil dispersion experiment was set up to clarify especially acute impacts on the mangrove seedlings.

(i) **Materials and Methods:**

The oil dispersion experiment was established at Karamjal Wildlife 13reeding Centre and Mangrove Park under Chandpai Range. Three major species in the Sundarbans i.e. Golpatta (Nypa fructicans), Sundri (Heritiera forms) and Gewa (lixcoecaria agallocha) have been tested using Fuel, Petrol and Diesel oil for treating. I'he seedlings used were 16 weeks. 6 weeks and 10 weeks old at the beginning of the experiment for Golpatta, Sundri and Gewa respectively. The concentrations of oil products were made 0.1%, 1% and 10% mixed with river water. Chemically dispersed oils were also applied to the seedlings in order to compare the toxicity and assess the effect of oil dispersant (Shan Chemicals S-510), which were available with the Mongla Port Authority. For each treatment, 4 replicates were placed into plastic bucket (14 I,), and then one litre of oiled water with/without dispersant chemical was given. Duration of exposure to oiled water was 3 days. The controls, which received no oils and dispersant chemicals, were also set apart. The survival rate, numbers of leaves and any damage caused have been observed periodically.

(ii) Species Tolerance against Oils:

The changes of number of leaves in three species after treatment with three kinds of oil were recorded. The survival rates of three species one month after the different oil applications with or without adding the dispersant chemicals were noted.

This preliminary experiment needs more time to lead to any conclusion. However, observation of just one month period showed that Diesel appears to he most toxic to the three species, followed by Petrol and Fuel. Fuel is less toxic especially to Sundri and Gewa. The Gewa seedlings were found to be more tolerant against the oil products rather than Golpatta and Sundri. Sundri is most vulnerable to Petrol and Diesel. Beyond expectations, the oil dispersant chemical used in the experiment was not effective but more harmful to the mangrove seedlings tested, especially when applied to the higher concentrations of oil treatments. Probably this fact needs further investigations in the open fields, because toxicity of the dispersant itself may he high enough to the mangrove seedlings and the opportunity of contact with dispersed oils may not he reduced in the closed system like the experiment. Damage symptoms seen within one month were burning, yellowing, witting and shedding of the leaves, which led to subsequent mortality of the seedlings.

The general description of oil spill impacts on mangroves is shown below:

Time after Spill	Impact
0 - 15 days	Death of birds, turtles, fish and invertebrate
15 - 30 days	Loss of leaves and death of" small mangroves
30 days - 1 year	Loss of leaves and death of medium sized mangroves
1 - 5 years	Death of large mangroves, some re-growth of seedlings
1 - 10 years	Reduetion in survival of seedlings and problems of re roduction
10 - 50 years	Possiblc recovery of mangrove site

Source: ISMS, 1995

Table: Impacts of Oil Spills on Mangrove Ecosystems

The loss of leaves from mangroves, and their subsequent death, was observed over the period of 3 years following the spill of nearly 3 million liters of crude oil on to the coastlines of Puerto Rico in 1977. Similar effects on mangroves were also observed after oil spills along the Atlantic coast of Panama and the Pacific coast of Colombia and Equador. In 1997 a ship ran over its own anchor as it was mooring in Botany Bay on the coast of Australia. The anchor punched a hole in the hull and 100 tons of Arabian crude oil was released. The oil contaminated stands of Avicennia and Aegiceras Lip to about I meter above the mud surface at the front of the swamp and to lesser heights further landward. The heavily oiled small mangroves seedlings died almost at once as did most of the heavily oiled lower leaves of the more mature mangroves. Two years after the spill, large areas of mature mangroves had died. I Tfects of water related petroleum pollution on mangroves were reported by Tsuruda (199 I).

The study of **the small scale of oil dispersion experiment clarified the acute oil impacts on 3 species of Sundarbans mangrove seedlings in the closed circumstances** . The further **investigations through long-term monitoring** will he required **in order to assess the chronic oil impacts on the mangroves.**

7.3.4 Socio-Economics

The socio-Econo►nics aspect of the SRF management is complex and diverse subject. It is only in comparatively recent times that the increase in population has led to extreme pressure on the Sundarhans ecosystems. Local communities living in the periphery are greatly blessed with immense natural resources provided by the Sundarhans mangrove systems. A large number of wood cutters (Bawalis). honey harvesters (Moualis). Fishermen (.Iailas) and mollusk shell collectors are there to survive. About 46% of all local income being derived directly from the Sundarhans resources (IAO/UNDP. 1998). The economically important plant species in the SRF are Sundri. Bacn. Doran. Gewa, Passer, Dhundul, Golpatta and others- A total of 2.0 million cIt of Gewa timber was to be supplied to Khulna Newsprint Mills and Match Factories in Dhaka annually, which in subsequent period has increased substantially. Approximately 20.000 ton of Doran are extracted (Dey, 2001). Thanks to the discovery of natural gas and its use in industries and domestic use as fuel reducing the load on extraction of wood from Sundarbans. I lowever. the western and south western zone still being outside the gas supply network, population in the areas have been using the wood as source of fuel.

(i) Human population and settlement:

There are no permanent habitations inside the SRF, but those living in the border area are about 2 million and at least 25% of this population is probably engaged in some full or part-time activity in connection with products from the SRF (IAO/UNDP, 1998).

(ii) Fishermen:

There are about 10,500 numbers of licensed fishermen to do fishing in the Sundarbans according to the Forest Department (Dey, 2001) besides the numbers unrecorded. The Fishermen alone represent about 48% of the forest dwellers in the Sundarbans. The total **landed fish harvest estimates range between** ***12,000 to 5(1,000 ton.***

7.3.5 Mapping

(i) Estimated Oil Impact Zone:

The Study area of this Oil Spill Impact and Response Management Program is the shipping lane along Pusur River from industrial town of Khulna to down south of Hiron Point. The Sundarbans Reserved Forests (SRF) extends southward from Dhangmari where is located only 3 kin south of Mongla Port. Oil spill impact largely depends upon tidal regime and climatic conditions of the specific time and season. adding to the property and amount of spill oils. The whole mangrove vegetation in the Study area of the SRF is vulnerable to the oil pollution more or less. The most heavily affected areas among them appears to be such places as Sundri-dominant area. lower ground level, gentle inclined shore, inner fringe and basin, muddy flat. and direct contact points to the landed oil.

(ii) Environmental Sensitivity Map:

Sensitivity map conveys essential information to the oil spill responders by showing environmentally sensitive areas and coastal resources for the risk assessment and monitoring purposes. Mangrove stands as well as fish spawning and bird breeding sites are included in the ecological sensitive areas.

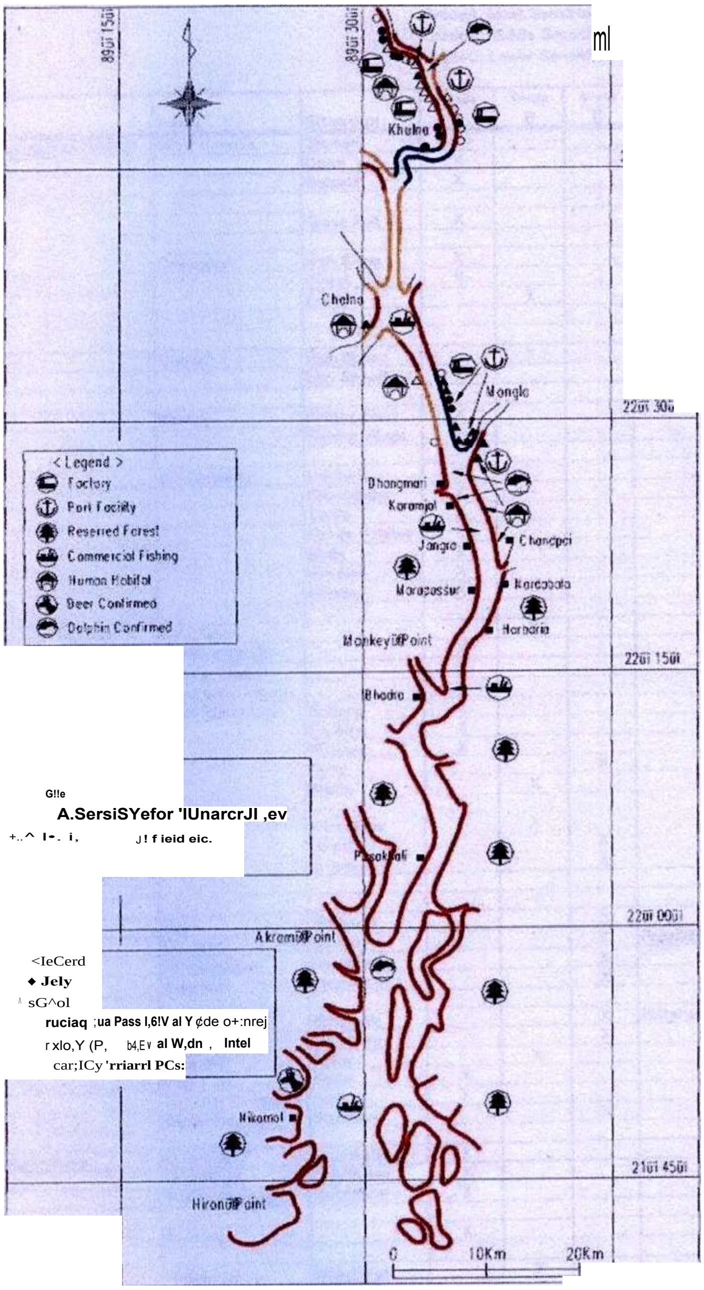
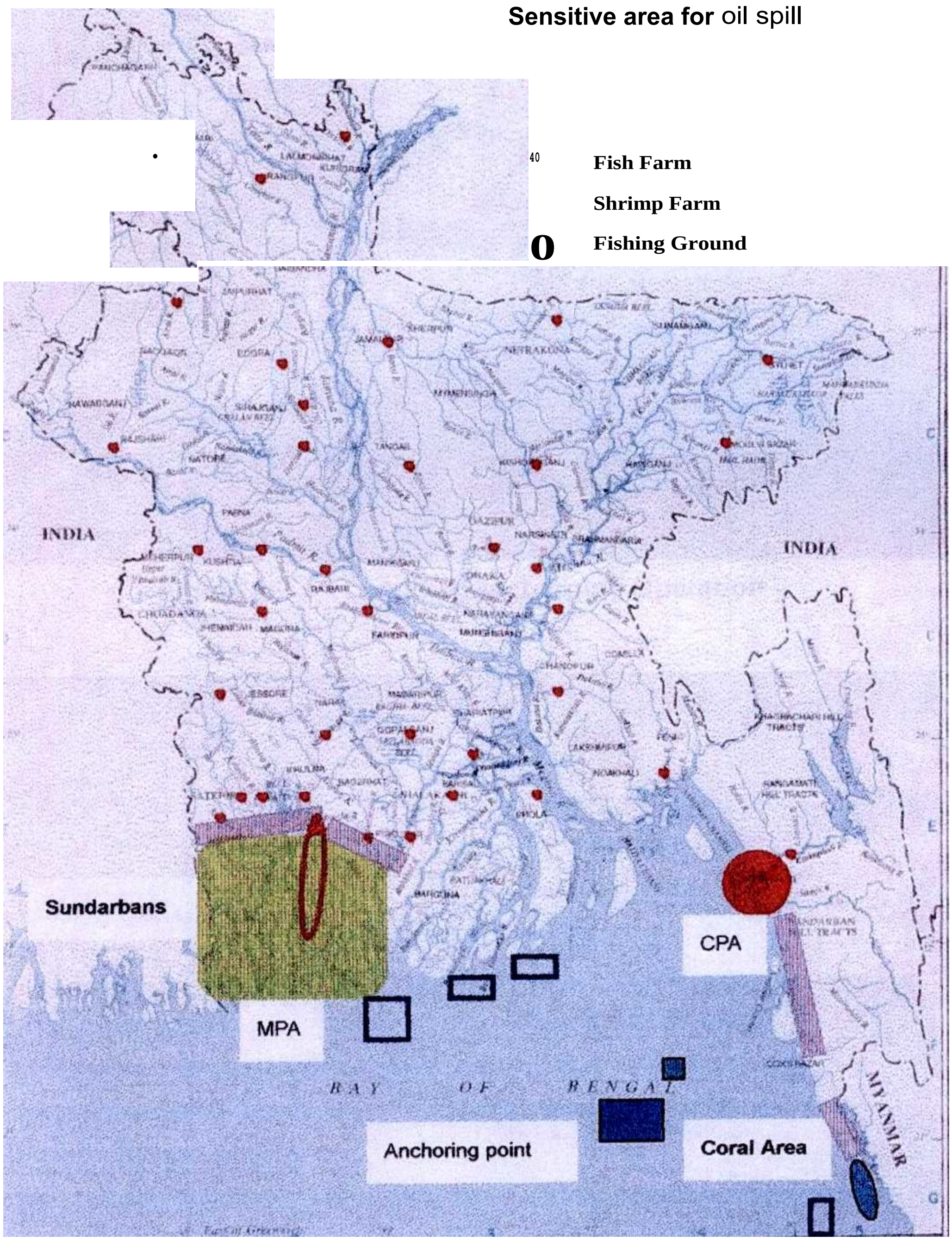


Figure: Sensitivity Map



Sensitive Area to Oil Spillage

Source: Bangladesh petroleum Corporation

(iii) Integration of Results into GIS:

The Integrated Data Base (IDB) of the SRF, which incorporate the GUS data base are valuable for planning and decision making of the proper management of the Sundarbans mangrove ecosystems (FAO/UNDP, **1998).**

The GIS data base is to be linked ultimately with the Forest department's data base unit, which referred to as the Resource Information Management System or RIMS.

All data and information collected in the process of Environmental Sensitivity Map of the Study Area should be integrated to the existing GIS data base to facilitate the oil spill response planning, monitoring, and assessment of ecological risk and impacts.

7.3.6 Risk assessment

(i) **Oil Spill Impact on Mangroves and Other** Living Creatures:

Several oil spill incidents in Pusur River have been reported and the spills from a foreign vessel M.V.Pavlin-I were one of the latest and most hazardous cases. The ship submerged near Bani. Santa village in August 13, 1994 and heavy fuel oil had been leaked from 193 metric ton of tanks, was flowing down up to about 20km downstream. It was reported that marshes, plants. grasses, mangroves. paddy fields, cattle grazing grounds, fishing grounds, shrimp ghers, and some dwelling huts were badly affected by the oil spill. Oil layers were found deposited on the plants, on Golpatta leaves, and on long grasses.. Some marshes were dead. Cattle were grazing in the oiled fields and getting affected. It is indispensable to accumulate the base-line data of post-oiling behavior of mangroves and other living organisms for the risk assessment purposes.

The indicated sheltered creek systems in the SRI may act as an oil trap. with serious effects **on the mangrove and fauna . If oil penetrates into far** inland. The **inner fringe and inner basin types of mangroves are likely to be most susceptible to the spilled oils.**

Climatic conditions are also important factors for the assessment of oil spill impact. High temperatures and wind speeds increase evaporation, which leads to decrease in toxicity of oil on the water. Temperature determines the rate of microbial degradation in the environment, so the oil occurred in summer may have high possibilities of biodegradation. Winter oiling may affect large groups of migratory waders.

(ii) Chronic Impact Persisting for Longer Periods:

Recovering times following oil spills can vary from a few days to more than 10 years. Extent of oiling. Oil types, geographic features. time and season of the spill forest type affected. and climatic conditions, are important in assessing the chronic oil impacts on the mangrove ecosystems.

Severe oiling from spills of mangroves leads to partial or complete loss of leaves; trees that lose all their leaves generally do not recover. Sometimes a totally devastated mangrove forest may tale several decades to return to a fully mature state (IMO. 1988).

Penetration of oil into the sediments is likely to **be greater in the case of peaty soil and in areas with many crab burrows or dead and decaying roots, which leave pores in the sediments. Once oil has trapped in the sediments it may remain there for long time and gradually seep out over some years, causing chronic pollution** (I MO. 1997).

7.4 Oil Spill Modeling

7.4.1 Introduction

In the Sundarbans forest and its adjacent areas including around Mongla Port, water pollution is advancing due to oil spilling from ships as a result from normal operation and accidents and thus causes serious environmental damages. Therefore, it is essential to grasp the diffusion mechanism of spilled oil in advance. for planning and implementing the protection countermeasures to tackle the oil spill disasters.

The PUSUr **River connecting the Mongla Port and the** Bay of Bengal is the main **sea route** for freight **transportation**, **cargo vessels and container** ships that frequently ply there. The **region has characteristic** climate and each season, strong monsoon and fogs like **inclement** weather condition **arise there**. Consequently ships are always exposed to the risk of **oil spill accidents due to collisions** and grounding because of weather condition and other **reasons.**

In Bangladesh, particularly in the southwest region, there were cases of ship collision and accidents in the Poser channel resulting into oil spill in the region. There also exists serious possibility of grounding of ships laden with oil threatening large scale oil spillage. The major oil spill accidents in 1994 caused serious environmental degradation due to spilling of crude oil from the ship MT. Pavlina sunk in the Pusur River near Mongla Port. It is also known that about 1.5 million gallon of oil-water mixture is being dropped down in the Pusur every year.

In order to reduce the damage of oil spill accidents to a minimum, it is important to understand and specify the oil spill situation resulting from such accidents. Specifically, it should be a quantitative grasp of the casual relation of different factors between the behavior of oil diffusion (i.e. the direction and distance of oil diffusion according to many physical factors such as winds and water streams). qualitative change of spilled oil with ti me.

The described oil diffusion model is one of' the effective solutions for this comprehension. The model formulates the complicated behavior of spilled oil. Accordingly it is possible to grasp qualitatively where and how much oil is distributed. as well as the oil properties. In addition, it can be used to evaluate the effectiveness of conservation measures at the time of accidents.

The purpose of developing and using oil spill model:

The main purpose is to predict the position and volumes of spilled **oil on surface water and apply the model as useful tool for:**

- **Making contingency and monitoring plan**
- The risk **assessment**
- **Response and clean-up operation**

7.4.2 Oil **Spill Model**

- **Basic equation**

The model used in this study is based on the model developed by Shen et al (1991) and Yapa (1994) who presented the equations for two layer-dimensional systems. If' we assume the thickness ot'surface layer is negligible in comparison to the water depth, then the equation become

BCS/ SCt + (S/ bx (us CS) + S/ Sy (vs CS)

= Dx S2 Cs/ Sx2 + Dy S2Cs/ Sy2 + (aI VbCv - w Cv).=o- y Cs - SF: -- SD+ Ms(x,y) - Ds(x,y)

Where, x, y and t = space and time variables;

Cs = local oil concentration in the surface layer per unit area

Cv local volumetric concentration of oil in the water column per unit volume of water

Us and vs = the components of surface drift velocity in x and y direction respectively

Dx and l)y = diffusion coefficient in x and y direction respectively

al a coefficient representing probability of oil droplet reaching the water surface

Vb -- buoyant velocity of suspended oil globules

y - a coefficient representing the rate at which the surface oil is dispersed into the water column

SL and St, = rate of evaporation and dissolution per unit area of surface slick respectively

MS = effect on the distribution of surface oil by mechanical spreading and

D = effect on the distribution of surface oil by shoreline deposition.

The concentration distribution in the water column can he described by

SCv/ SCt + 6/ ax (u Cv) + S/ Sy (vs Cv)

=Dx62 Cv/0x2+Dy432Cv/6y2+(al Vi Cv- y`Cv),-o-yCs--Es-SDI E0' (2)

Where a and v = components of current in x and y direction respectively

a = a coefficient representing the rate at which the surface oil is dispersed into the water layer below

EB = effect of oil dispersion on the bed

SD = rate of oil dissolution per unit volume of water and

E»' = effect on the distribution of oil in water column due to emulsion.

Equations (1) and (2) can also be written in Lagrangian form, and be simplified by combining with the mass conservation equation of water. The advection and diffusion are the main processes. These equations can be solved when the hydrodynamics are known.

In this modeling, a hydrodynamic model computes current patterns in the Pusur River and the using the computed current velocity Lagrangian discrete-parcel method approach for equations (I) and (2) is applied.

- Weathering process:

The following **sub-models are introduced** by Shen and Yapa et al (1991). In this study, they are employed **in oil spill model** of the Pussur River. Details are described as follows:

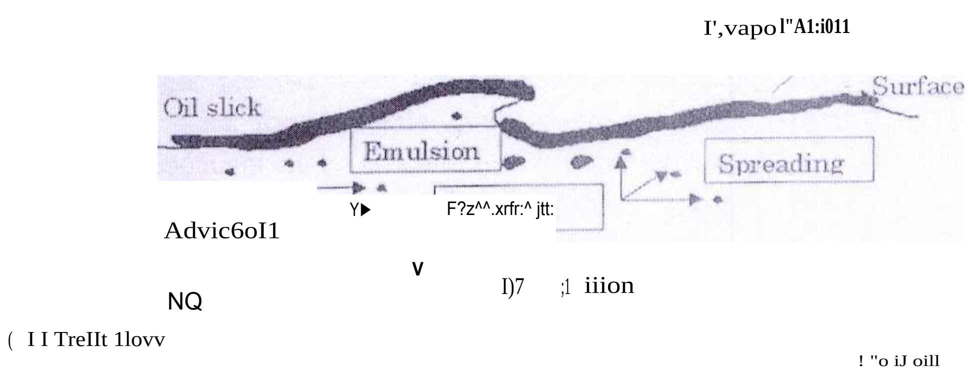


Fig: Fate of Spilled Oil

Source: ISMI:. 1995

1. **Advection:**

Advection is a physical process that involves the drilling of the surface oil slick and the subsurface oil. It is the **main mechanism** governing the location of oil spreading. Location of the spreading of slick oil is important know to understand its impact on the environment of that location and its concentration for taking mitigation measures. The combined effects of surface current and wind drag cause the advcction of surface oil. The advective velocity of each oil parcel van be computed as

vt=v + V' (3)

where vt = drift velocity of an oil parcel

v and v' **are the mean and turbulent** fluctuation components of the drill velocity. The component of drift velocity of oil is included to simulate the horizontal diffusion of oil parcels. The formulation for v' will be discussed in subsequent section on horizontal diffusion.

On the surface layer, the mean drill velocity **is considered** to he a vector **sum of a wind - induced and water current-induced** drift. The mean drift velocity **v on the surface can he calculated by the formula:**

v = aw vw + vs (4)

where,

vw= the wind velocity at 10 meters above the water surface

vs surface water current and

a, wind drift factor to account for the drift of surface slick due to wind effect.

In general aw can vary between 0.0 and 0.06 (Stozenhach ct al.. 1977), but 0.03 has been the commonly used for aw.

2. Horizontal **diffusion:**

The term v' in equation (3) accounts for the horizontal turbulent diffusion due to the turbulent fluctuation of the drift velocity. Based on the random walk analysis

v' _ (4D,/6&)' 2	(5)
and v' = v' Rn e	(6)

where,

6t = time step

D-r= diffusion coefficient

Rn - a normally distributed random number with mean value of 0 and a standard deviation of I. The directional angle 0' is assumed to be a uniform distributed random angle ranging between 0 and t.

DT is strongly related to turbulence. In the ocean it has to be estimated based on available data or past experience. Values used for D, vary widely. In l'lliot ct al's dye experiments horizontal diffusion coefficient of 2,000 cm'/s were measured. Based on surface dye patch experiments. Okubo provided a relation between D, and time as given below

D, = 0.0027t'." (7)

Where D, is in cm'rs ; and t = time in seconds.

In rivers. the diffusion coefficient is affected by the shear velocity a and the depth of flow h:

Dr - 0.6 hu (8)

3. Mechanical spreading:

Mechanical spreading is the horizontal spreading of the surface oil slick due to the imbalance of forces of inertia, gravity, viscous and interfacial tension. Although in violent turbulent conditions, the oil slick may break up into smaller patches before mechanical spreading can take place. In general, mechanical spreading is the mechanism that causes the rapid expansion of the slick in early stages.

Fay considered an oil slick to pass through three phases of spreading. Immediately after the spill, the oil slick is rather thick. Therefore, in the first phase gravity and inertia forces dominate the spreading process with gravity being the accelerating force and inertia the retarding force. As time progresses the oil slick becomes thin and the inertia force becomes relatively unimportant. In the second-phase the gravity and viscous forces dominate the spreading with viscous force being the retarding one. As the slick gets thinner interracial tension and viscous forces dominate the spreading.

- **Evaporation**

Evaporation begins immediately after the spill. Evaporation is the main process that causes the loss in oil volume during weathering. The amount and rate of evaporation depend on the slick **area**, oil vapor pressure, ambient temperature and wind speed. As the spreading of the surface slick occurs, more of the hydrocarbons are exposed to the atmosphere, causing the evaporation to increase. In the modeling equations this process is accounted for by the term SE in equation (1) . Mackay. et at. developed a formula for calculating the rate of evaporation. The volume fraction of oil evaporated is determined **as**

F = ar (I /C) [In Po + In (C Kr t + I /Po)] (9)

Where, at = modification coefficient introduced in the present study to account for the effect of the change in oil property on the evaporation rate due to emulsification and other weathering processes; Kr t is the evaporative exposure term. which varies with ti me and environmental conditions, K[_ mass transfer coefficient, m/s, Po is the initial vapour pressure.. C is constant number determined by oil type.

- **Dissolution:**

Some of the same oil components, which are subjected to evaporation, can also dissolve into the water columns from a surface slick. Only the low molecular-weight hydrocarbons have an appreciable solubility in water. The fraction of oil dissolved is very small in comparison to the oil that is evaporated. I lowevcr, this process is important due to the toxicity of the dissolved oil fraction. In the modeling equations this process is accounted for by term Sn in Equation (1).

In the present study, the formula of Lu and Polak is used. which provides more information on solubility. In this method the rate of dissolution is calculated as

ni Cd cxp (-0.1 t) (10)

in which, ra = rate of dissolution, mgm day , C and d are dissolution coefficients determined by oil type, t is the time in hours.

- **Emulsification:**

Mixing of oil and water causes the emulsification 01 '011. The emulsification **results in a substantial increase in the apparent viscosity and** volume of' the surface **layer due to the increase in water content in the slick.**

7.4.3 Model **Structure**

The model can calculate the distribution of spilled oil on surface water through physical process (advection, diffusion and spreading). the change of oil volume and property of the oil through chemical process (evaporation, dissolution and emulsification). The results can be used for counter measures, the risk assessment at the time of the spill accident.

The Fig. 7.4.3 below shows the structure of the oil spill model. The model is composed of' the following parts:
Input and output of the model and sub-models, which can produce the distribution of spilled oil and the change of the oil volume and the property through physical and chemical processes. It uses the flow data calculated by the hydrodynamic model.

Input

- **Spill location and duration**
- **Oil volume and** properties
- Topography
- wind velocity and **direction**

Physical process sub-models

Current advection
Horizontal diffusion
Mechanical spreading

Output

- **Oil Distribution**
- **Amounts of evaporation, dissolution, emulsification**

Hydrodynamic data		**Chemical process sub-models**
• Water **velocity and direction**		• **Evaporation** • **Dissolution** • **Emulsification**

Fig. 7.4.3: Model **Structure**

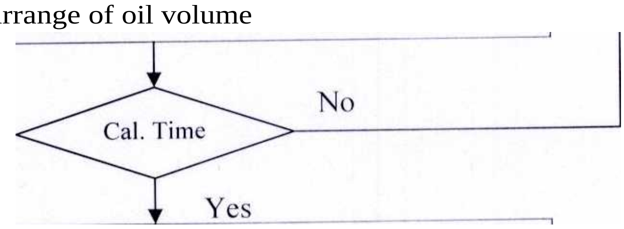
- **Calculation Flow of Oil Model:**

The computer code in the program for the Oil Model is written in Fortran. The program consists of main program and 36 subroutine programs. Graphic user interface program for input and output are written Visual Basic. Thus the program structure becomes as shown below:

Open files

Read input data
Topography, **Water depth, Boundary,**
Oil spill site, Oil spill volume. Oil type
Flow velocity and direction. Wind velocity and direction

Calculate	advection of oil particles in surface water
Calculate	emulsification
Calculate	evaporation
Calculate	dissolution
Calculate	spreading
Calculate	arrange of oil volume



Write output data
Oil position (latitude, longitude). oil volume
Time series data of oil volume and oil property

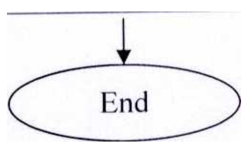


Figure: Block **Diagram** of oil spill program

- **The operation flow of oil spill model:**

Graphic **user** interface is employed to operate easily for users. Input parameters are chosen to minimize the operation time. It can be expected to response quickly when oil accidents happen.
The operation flow is shown below:
The model consists of three functions:

- Set the calculation area
- Set the input parameters
- Display the calculation results

Start up main menu

Set the **calculation area** Set spill point

Set the input parameters

Control parameters:
Oil volume, the number of oil parcels, Time step, Period of oil spill.
The coefficient of horizontal diffusion

Weather parameter:
Wind data (velocity and direction), Wave data (period and height),
Air temperature, Water temperature. Wind coefficient

Oil properties:
Specific gravity, Viscosity, Water content, etc.

Run model Monitoring calculation progress

Display the calculation results
Distribution of oil parcels
'l'i me series of oil volume (Total Evaporation. I;mulsitication. Dissolution)
Time series of oil properties (Specific gravity. Viscosity, Water content)

End

Figure: **The Operation flow of oil spill model**

The model can forecast the distribution of spilled oil ahead of' 2 weeks in a few in'Mutes and can work in PC. Required hardware and software environment are as follows:

- CPU: Pentium 3 or more than 650 MHz (e.g. DELL Optiplex GX 150 MT/886 P3)
- Main memory: 128-256MB
- Hard disk volume: 1-10 G13 (as virtual memory)
- Display resolution: 1024 X 768 dot , OS: Microsoft Windows98

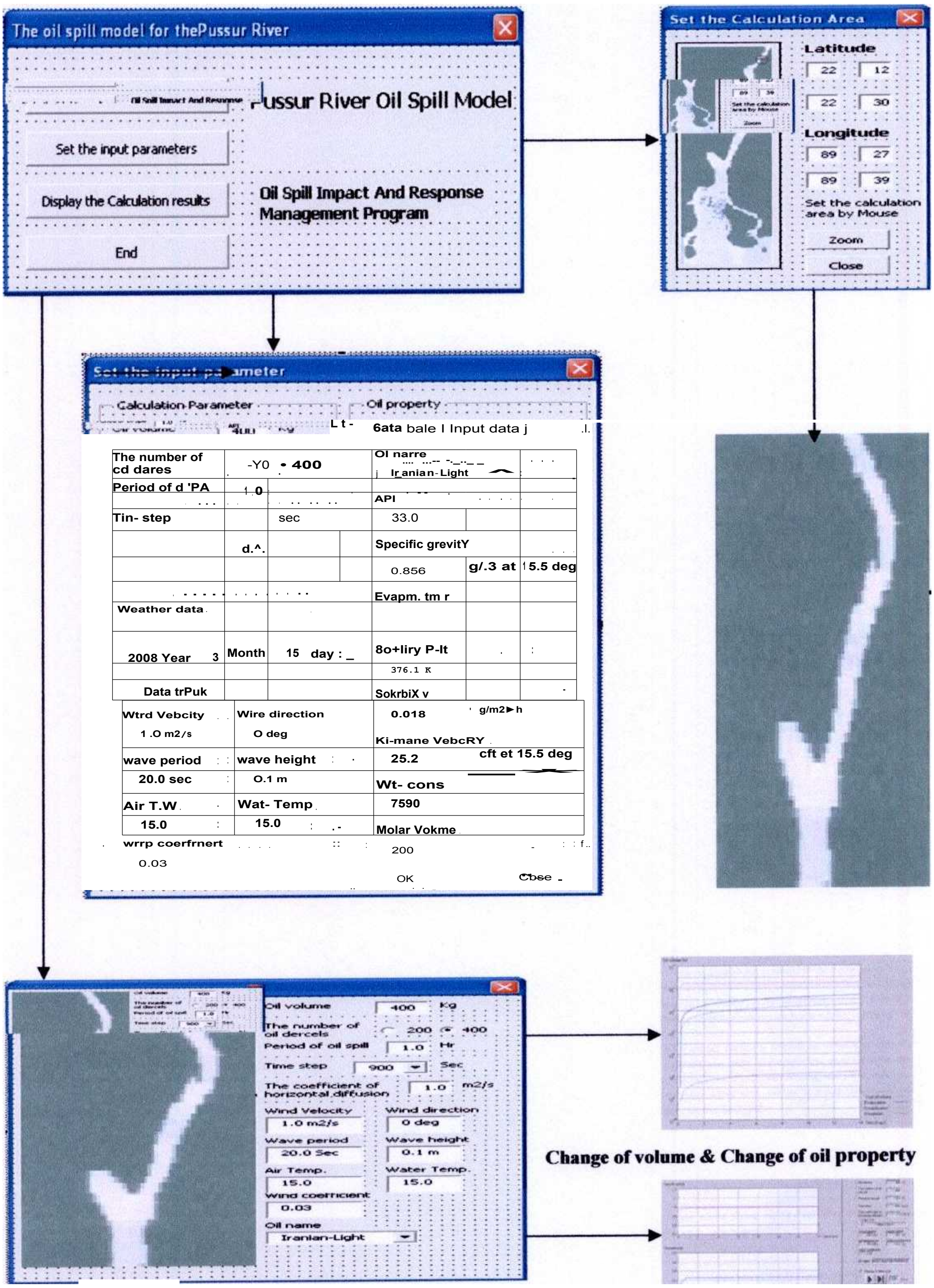


Figure: **Input and** Output of Model

7.4.4 Gathering Environment Data of the Study Area (Pusur River)

The behavior of spilled oil on surface sea is determined by environmental conditions such as wind, current and wave. In this section, a part of environmental data applied the oil spill model is shown.

(1) Topography data

Topography and depth data are based on depth charts (No.732 published in U.K.2000). The calculation domain is related to the Mongla Port limit as shown below (Longitude 89 20' - 89 40' and Latitude 21 27' - 22" 50')

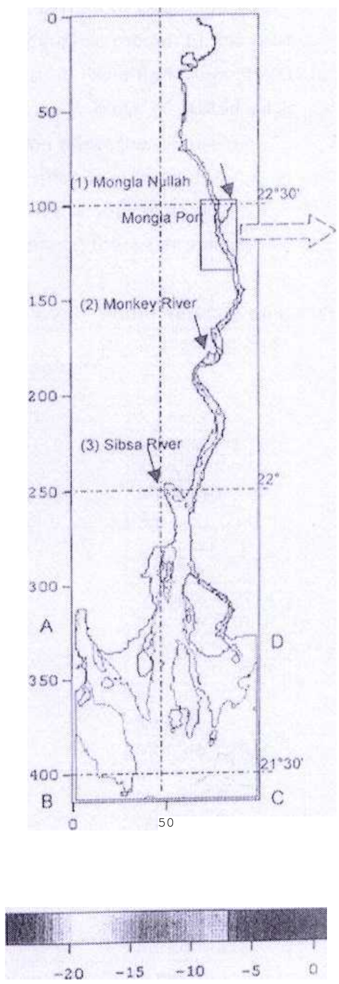


Figure: Calculation Domain

The calculation domain is divided into several small grids enough to represent the width of river.

- **Grid size in x - direction** : **Dx = 12" = 340mm (number** of grids **is 100 in x-direction)**
- **Grid size in y-direction** : Dy = 12" = 340mm (**number** of grids is 415 in y-**direction)**

The total number of grids 100x415 in the calculation domain.

The open boundary condition is set on the line A-B-C-I).

The channels that add discharge into the Pussur River are shown in (I) (3).

(2) Hydraulic data

(a) Water velocity

It is important to grasp the water velocity in site For comparing with calculated data by hydrodynamic model. It this study, water velocity is measured in field surveys along the Pussur River from August to March 2002. As most of oil spilled is on surface water, the surface water velocity and direction affect the oil position. The observed data are summarized in the table below. The water velocity is within I.Om/s in most measuring site except at Mongla and Monkey Point where velocity is over I.Om/s in August. Even at upstream like Mongla, the water velocity is affected by semidiurnal tide.

Time of measurements	**Measuring Site**	Water Velocity **(m/s)**	I'ype of Tide
August 2001	Chalna Point	0.76	I;hh
	Mongla Port (1st)	0.91	I:bh
	Mon la Port (	1.60	;bh
	Mon la Port(2	1.67	Flood
	Monkey Point	1.39	Flood
	Akram Point	0.96	1hh
January 2002	Chalna (1s`)	0.42	Hood
	Chalna 2")	0.46	I' lood
	Mon la Port (I")	0.63	Flood
	Mongla Port (2"	0.45	";hb
	Mon is Port (3"')	0.59	flood
	Mon la Por[redacted]	0.56	I N)
	Mon Ala Port (0)	0.75	Hood

Time of measu re ments	Measuring Site	Water Velocity (m/s)*	't'ype of T ide
	Mon lrl a Po rt (4t)	0.87	I ;bh
	Mo n gla Po rt (5"--	0.48	lood
	Mon la Port 6`'	0.50	:bb
	Monkey Point (I s)	0. 42	I' lood
	Monkey Point (2")	0.51	I,: bh
	Akram Point	0 .28	I lood
	Hiron Point	1.34	I :bb
February 2002	Mongla Port (! ")	0.99	I :bb
	Mon la Port (1'`	0.88	Flood
	Akra rn Poin t (1,"	0.69	I .hh

*\ later velocity is maximum speed during each measuring

(b) Water level

Calculated water level **is less than** 3m at Mongla Port in July. e semidiurnal tide is dominant and the double amplitude of tide is about 2.0111.

V, Hydrodynamic model

A two-dimensional hydrodynamic model was used to produce water velocity and its direction for oil spill model. To note that the river topography and riverbed of the Pusur River gradually changes with the time progress because of erosion and sedimentation, and according to the interaction between riverbed and river Ilow. the flow velocity changes as well. Strictly speaking a dynamic flow model that can take the interaction between riverbed and flow into consideration should have been used. In this study, the high accurate flow is not required. Because the grid size of the oil spill model as has been considered is 12 (about 340mm) and in that case the change of topography over 340mm may not be significant in one year and thus the revision of topography is not required immediately. But as and when the large-scale changes in topography happens. the topography data in the model should be updated accordingly.

- Verification of Hydrodynamic Model:

In order to verify the results by two-dimensional (2-d) hydrodynamic model, it is compared with calculated flow velocity by one dimensional model (I-d) that was verified with observed data. And it is also compared with observed data that is time series velocity data **measured** each half an hour at Mongla Port. The results of 2-d model are agreed with **that** of 1-d model and observed data. shown in 'f'able below:

Table: The Comparison of average flow between 1-d model, 2-d model and observation:

Cases	Model	Average Flow velocity (m/s)				
		Chalna	**Mongla**	Monkey	**Akram**	Iiiron
Flood (July)	1 -d	0.40	0.22	**0.1 3**	0.10	0.07
	2-d	0.33-0.38	0.15-0.29	**0.06-0.18**	0.09-0.12	0.05-0.07
	Observation (22Aug' 2001)		**0.16**			
Dry	I - d	0.12	0.07	0.04	0.03	0.02
(December)	2 -d	0.10-0.13	0.07-0.11	0.06	0.06	0.04
	Observation (**24 Jan** '2002)		0.08			
	Observation (17 Feb'2002)		0.10			

(3) Wind data

The wind has influence on the drifting surface oil. For predicting the oil position. the forecasted wind data after oil spill accident is needed. In Bangladesh the forecasted wind data has not been provided online in complete form from the meteorological department yet. In this study, available wind data was used. Monthly prevailing wind speed (in knots) and direction at Mongla station from 1991 to 2000 has been shown as reference in Table below. The monthly average wind speed has a peak in May. The prevailing wind comes from south in March to September and north-northwest in October to February. The wind speed is highest in May (5.0 knots on an average) and lowest in November (2.2 on an average).

Table: Monthly prevailing wind speed in knots and direction at Mongla

Year	Jan	Feb	Mar	Apr_	V1ay	Jun
1991	2.2 N	2.6 N	2.9S	3.9 S	6.1 S	3.0 S
1992	2.0 N	**3.0 S**	3.2S	4.1 S	3.9 S	3.6 S
1993	1.5 N	1.5N	1.9N	3.1 S	6.5 S	4.6 S
1994	3.6 NW	2.1 N	4.6S	4.I S	4.3 S	4.1 S
1995	3.6 N	3.5 S	3A S	4.0 5	4.4 S	4.6 S
1996	2.4 NW	2.6 NW	3.2 SW	4.4 S	5.85	4.7 S
1997	2.3 NW	**3.5 S**	**3.2 S**	4.5 S	4.4 S	4.6S
1998	3.4 N	**2.9 NW**	**3.8 NW**	4.7S	5.2 S	4.8 S
1999	3.3 NW	3.3 NW	3.**4S**	4.9S	11.85	3A S
2000	2.9	**3.0 N**	**4.0 S**	4.6 S	4.1 S	3.9 S
Average	2.7	2.8	3.4	4.2	5.0	41

Year	Jul	Au	Sep	Oct	Nov	Dec
1991	3.2S	2.7S	1.85	1.9 N	1.9N	1.8 N
1992	2.9S	3.1 S	3.2S	1.7 NI:	1.8 N	1.9 N
1993	5.7SE	4.OS	3.OS	2.9 S	2.4 NW	2.4 N
1994	5.3 SE	4.O S	6.5 SE	2.6 S	2.3 N	3.0 N
1995	3.9S	4.OS	3.9S	2.3 NW	2.1 N \V	2.4 NW
1996	3.9S	3.8S	2.7S	2.3 N\V	1.8 NW	2.1 NW
1997	3.4S	3.8S	3.OS	2.2 NW	2.5 N	3.0 N
1998	4.OS	3.8S	3.4S	3.0 S	2.6 N	2.3 NW
1999	3.3 S	3.3 S	4.1 SE	3.6 E	2.1 NW	2.5 NW
2000	3.6S	3.5 S	3.OS	2.4 S	2.1 NW	2.3 NW
Average -	3.9	3.6	3.5		2.2	2.4

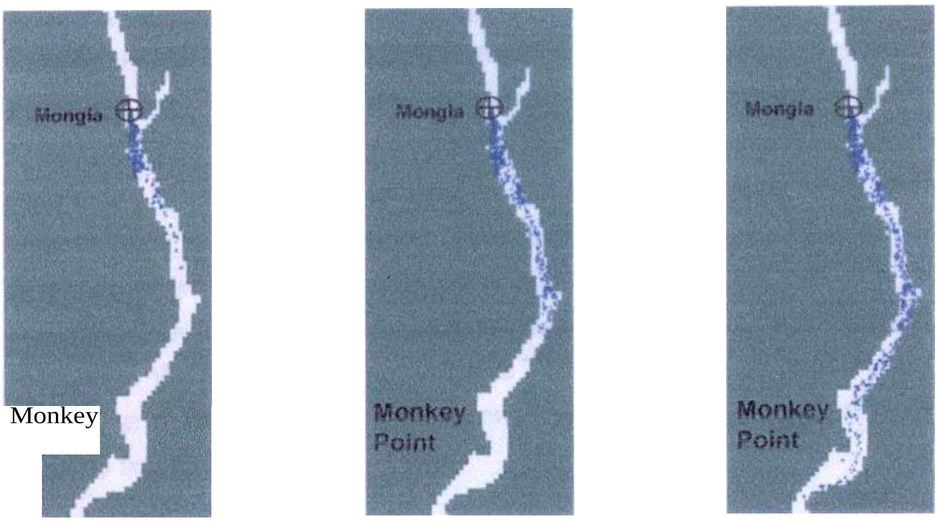
Source: Climate Division, **Bangladesh** Meteorological Department

7.4.5 'Trial use of the Model

Trial use of the model was carried out with the available data. In this stage. the precision of the data is not a major concern, as the model is used provisionally. It should be intended to consolidate and complete the essential data set for the model, including actual bathymetry data. wind data, hydrodynamic data of the target/study area and oil property data to understand the effectiveness of the model and future use at times of accidents.

Through the trial use, wind data and its parameter are most inlluential on the calculation of the oil position. About wind parameter in this model, "3`%o rule"" is applied (Ref. equation 4 under section 7.4.3). If the wind blow at a speed of 1 Om/s for example, the oil on water will be dragged at a speed of 30 cm/s (3`% of 10 m/s). It shows the possibility that the influence of wind is stronger than the average flow speed. Wind data and its parameters should be taken into consideration in the oil spill model.

H:xample of **the calculation result of the trial use** shown in following graphics:



12 hours 24 hours 72 hours

® : **Spill point**

Change in oil position with time

Calculation Condition:

•	Spill point:	Off Mongla Port
•	Oil volume:	200 KI (kilo litre)
•	Horizontal diffusion:	1.0 m2/s
•	Wind conditions (velocity and direction)	
•	Wind coefficient:	0.03
•	Flow condition:	flood season
•	Oil type:	low sulfur furnace oil

After 12 hours, the oil is at 20 km downstream of Mongla, after 72 hours, the oil is at the near Monkey Point from 25 km Mongla Port.

The wind blew at a speed of about 3 m/s from south. Wind coefficient is 0.03. Drifting aped of oil by wind is about 10 cm/s (= 300 cm/s*0.03) from south to north. The velocity of residual flow downstream of Mongla is 20 cm/s southwardly. According to the equation (4) of section 7.4.3, the oil drifting velocity is 10 cm/s. After 72 hours, the oil can reach at 25.9 km (= 0.1 cm/s x 72 hours). The oil position calculated is reasonable.

Figure below shows the time series of change of oil volume in each process like evaporation, **emulsification and dissolution**. **Evaporated oil sharply increases in 2 days.** After **that, it gradually increases till 14 days**. **Emulsified oil volume has the similar trend as evaporation**. **The volume of dissolute oil is very small. However**, **it can be not ignored due to the** toxicity of **the fraction of the oil dissolved.**

Figure shows the time series of change of oil property like specific gravity, viscosity and water content. These data are useful to choose the recovery method in response activity. Specially, it is difficult to suck the high viscosity oil by mechanical equipment. Prior to increasing viscosity up to higher number, the spilled oil should be recovered. Water content will give us the information about the volume of reservoir to prepare and the power of skimmer to separate oil and water.

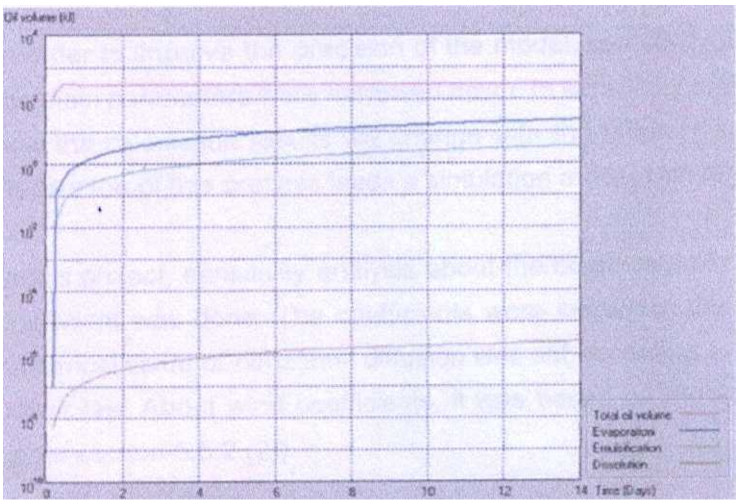


Figure: **The change of oil volume in weathering process**

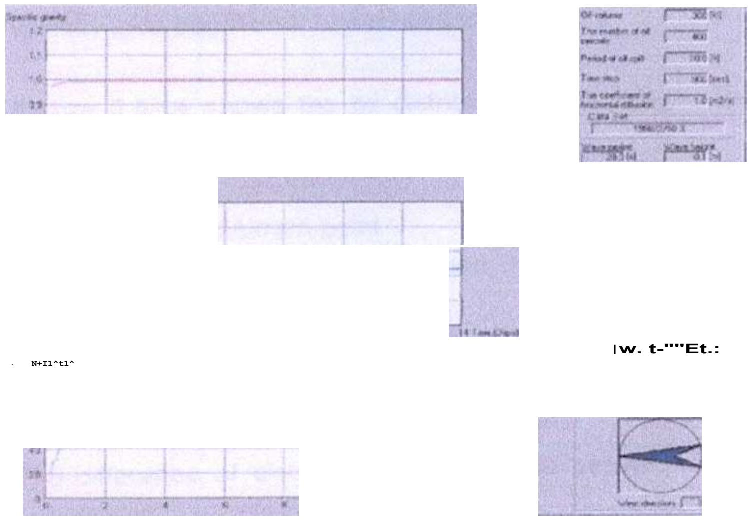


Figure: **The change of oil properties with time**

7.4.6 Sensitivity Analysis

In order to improve the precision of the model, sensitivity analysis was carried out and the main parameters were narrowed down. In sensitivity analysis, it is important to grasp how the calculation results will change the different value of the main parameter. Reiteration of this process leads to simulation model with high precision.

- **Horizontal diffusion**

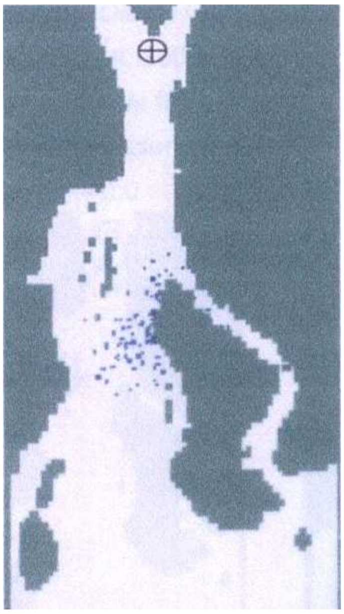
The coefficients of horizontal diffusion indicate the spreading speed of oil by flow condition. Generally, it is given by the condition of the depth of flow and the shear velocity (Ref. equation 8 under section 7.4.3)

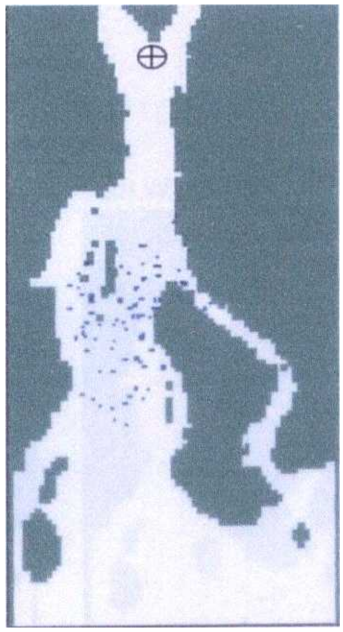
Figure shows the oil distribution after 2 days. The calsculation conditions are shown in the following:

•	Spill point:	Akram point
•	Oil type:	Diesel Oil (High Speed Diesel)
•	Oil volume:	300 kl in 4 hours\
•	Wind:	I m/s from north to south

- The coefficient of horizontal diffusion: 1.0 and 10.0 m2/s.

The difference of distribution of spilled oil between 1.0 m2/s and 10.0 m2/s can be recognized.





(a) Kh = 1.0 m2/s (b) Kb = 10.0 m2/s

E1 : spill point Wind: I m/s from north to south

Figure: Variation of oil **position with change in horizontal diffusion** after 2 days

- **Wind coefficient**

In whole area of Pusur River, the wind effect to spilled oil may differ with condition of spill points. In case of oil spill in Pusur river **area**, the wind effect to surface oil may decrease because of being obstructed by mangrove forest. While in case of the oil spill in Pusur river mouth or off shore, the wind effect may increase because of no obstruction.

The wind **coefficient is given in the following formula:**

V=W,V,+VS

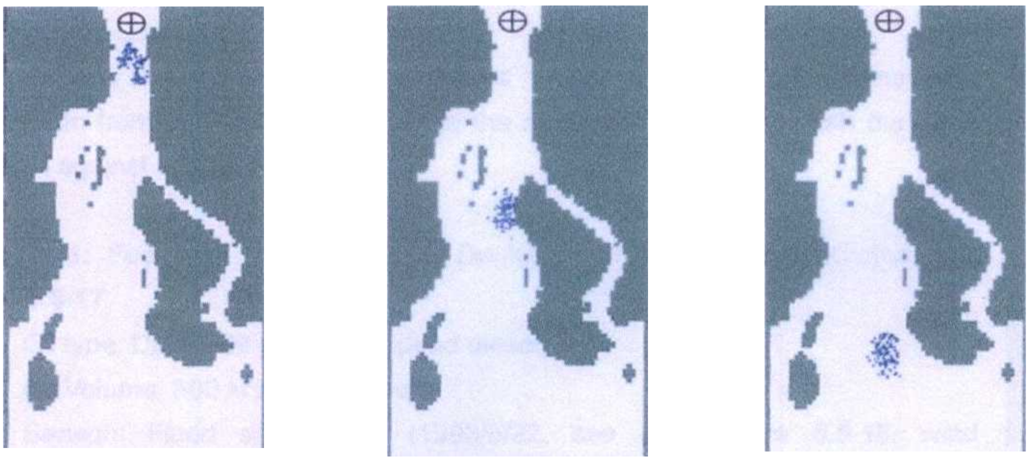
V: drifting oil speed, **W.: wind coefficient**, V,: wind velocity, V5: surface **water** velocity

Figure shows the oil distribution after 12 hours. The calculation conditions are shown in the following:

- Spill point: Akram point
- Oil type: Diesel Oil (High Speed Diesel)
- Oil Volume: 300 kl in 4 hours
- Wind: 10 m/s from north to south
- Wind coefficient: 0.0, 0,03, 0.06

Spill point ED

(a) W, = 0.0 (b) We = 0.03 (c) W, = 0.06



Wind: 10 m/s from north to south

Figure: Variation of oil position with change in wind coefficients after 12 hours

7.4.7 Case Studies

The purpose of the case studies is to prepare information for the development of a contingency plan and clean up operation. Five case studies are carried out with different scenarios as described in subsequent Figures. The case studies are selected in such a way so that it covers the different cases of oil pollution and oil-spill accident, which are expected tooccur in response to changes in the state of society in future. Five scenarios that have high risk of oil spill accident are based on the result of risk analysis. The results of such study are to be used for the contingency plan.

Scenario 1: Fuel tank damage at Daulatpur oil terminal, Khulna

Scenario 2: Oil cargo damage of MPA oil supply vessel

Scenario 3: Ship bunker cargo damage at Mongla M-4 point

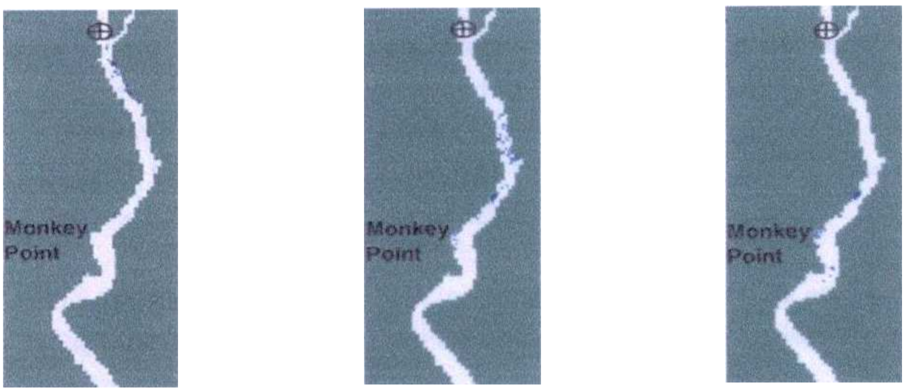
Scenario 4: Tanker collisions on Jaymani reach A-8 point

Scenario 5: Tanker collision on Monkey-Mazhar point

<u>Scenario</u> <u>1:</u> Fuel tank damage at Daulatpur oil terminal, Khulna:

- Oil type: **Diesel Oil (high speed diesel)**
- **Oil Volume**: **800 kl in 4 hours**
- **Season:** **Flood season**
- The coefficient **of horizontal** diffusion: **0.5 cm2/s**

After **one day**, **the oil is near spill point because the northward wind pushes the oil toward north**. After 14 days, **the oil reaches upstream Chalna**. tfi : spill point



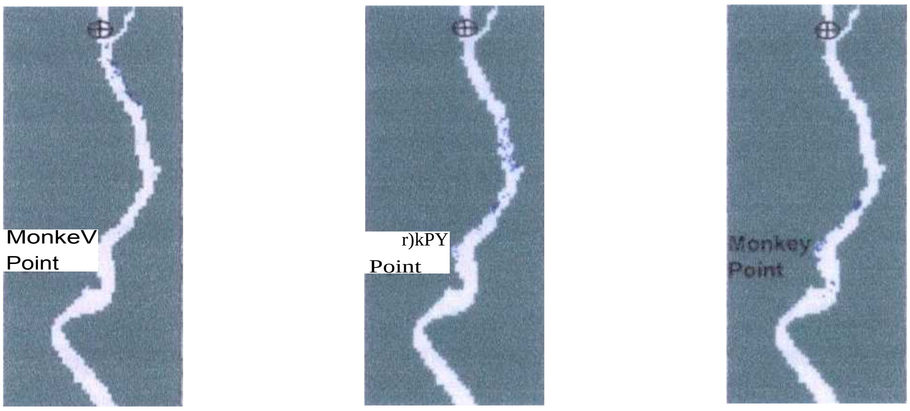
I day after 7 days after 14 days after

Figure: Distribution of spilled oil in each time for scenario I

<u>Scenario</u> <u>2:</u> Oil cargo damage of MPA oil supply vessel:

- Oil type: Diesel Oil (High Speed Diesel)
- Oil Volume: 120 kl in 1 hour
- Season: Flood season

After I day, the oil hit east bank downstream of Mongla port the northward wind. After 14 days, the oil reaches Monkey point



I day after 7 days after 14 days after

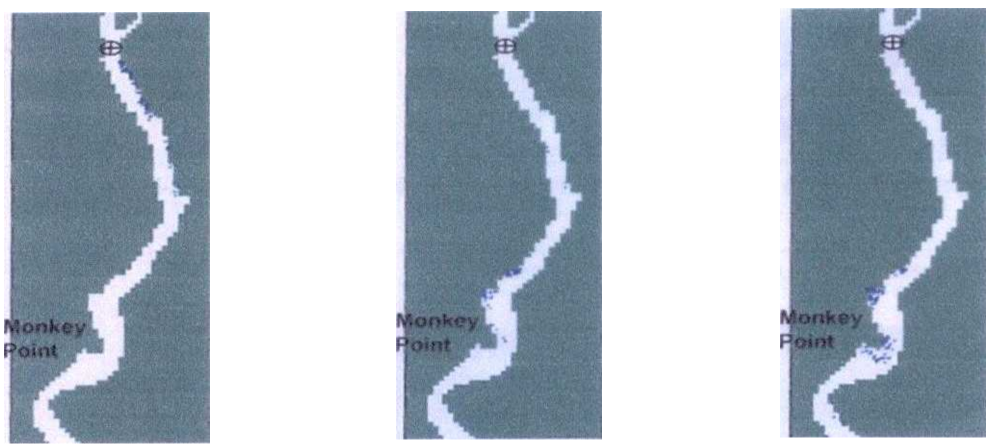
ff3 :Spill point

Figure : Distribution of spilled **oil in each time** for scenario 2

<u>Scenario 3</u>: Ship bunker cargo danmage at Mongla M-4 point:

•	Oil type:	Fuel Oil (high sulfur furnace)
•	Oil Volume:	450 kiln 4 hours
•	Season:	Flood season
•	The coefficients of horizontal diffusion: 1.0 cm2/s	

The distribution of oil for scenario 3 is different than that of scenario 2 onward sevn days though each spill point is close. Because the relative wind velocity and water velocity in space to the each oil position is different.



I day after 7 days after 14 days after

® :Spill point **Figure**: **Distribution of spilled oil in each time for scenario 3**

Scenario 4: Tanker collisions on Jaymani reach A-8 point:

•	Oil type:	Diesel Oil (high speed diesel oil)
•	Oil Volume:	300 kI in 4 hours
•	Season:	Dry season
•	The coefficients of horizontal diffusion: 1.0 cm2/s.	

The north wind and the flow push the oil to mouth of river after seven days. A part of oil **goes through the branch east** of the **mouth. It shows a possibility pf being set monitoring point in the branch.**

I day after 7 days after 14 days after

4,3 :Spill point **Figure**: **Distribution of spilled oil in each time for scenario 4**

Scenario 5: Tanker collision on Monkey- Mazhar point:

- Oil type: Fuel Oil (high sulfur furnace)
- Oil Volume: 300 kI in 10 hours
- Season: Dry season: 1.0 cm2/s

The oil position after 14 days is off shore in the Bay of Bengal. For the prediction of the oil position in the Bay of Bengal not only the tidal current but also the ocean current should be concerned.

1 day after 7 days after 14 days after

®: Spill point Figure: Distribution of spilled oil **in each** time for scenario 5

7.4.8 Contemporary Models and its Comparison

Description of Incident– Accident	Description of Model	Parameters considered	Remarks
On December 12, 1999, the Erika tanker broke in two sections at about 30 miles from Britany coast in the Bay of Biscay, France. The two parts of the wreck sank a few hours after the break. Some 15,000 tons of heavy fuel were released into the marine environment. It is the most serious discharge that has occurred in France since 1980 (Tanio, 6.000 tons). The nature of the incident, the kind and quantity of oil spilled, and the prevailing weather conditions posed considerable **response** problems. The spilled oil drifted for 2 weeks before reaching the coast.	Three different models were used by CEntre de Documentation de Recherche et d' Experimentations sur les pollutions accidentelles des eaux (CEDRE) within a couple of hours of the Erika sinking. On December 14, it appeared that the forecast of the MOTIIY model was closer to reality. The three models were: MOTHY (Meteo-France), OSIS (BMT, UK), and OILMAP (ASA, USA). It appeared that the forecast of the MOTHY model was closer to reality. The MOTHY model **was developed by Meteo-France (the French national weather service) to simulate the movement of**	Spill size, type, location, time of' occurrence, localized current. wind and other **environmental parameters like temperature. seasonal** factors **and diurnal** effects.	**The differences between model MOTHY and the two other models can be explained by nature and quality of the environmental data (winds. currents) and their processing within the model.** Thus. **the environmental data and the calculation of drift are controlled from beginning to the end by marine forecasters. The forecasters know the quality of the data input. According to the weather situation, the** forecaster **is able to say which model will be better than the other. The calculation of the currents by it hydrodynamic model allows a precision much better than that of currents resulting from databases or calculated by a percentage the wind speed.** It will be necessary in the future to improve the monitoring of the spills and to include in the operational choices a more scientific weather concern. ']lie use of forecasting must be reconsidered to draw the trajectory of the pollutants, but also strategy of observation and management of fight, evaluation of risks, etc. In it similar long drift case. with the knowledge that the observation is very difficult, it would be useful to systematically check each day at the location forecasts the previous days, if traces of pollutant are there or not.

Description of Incident- Accident	**Description of** model	**Parameters** **considered**	**Remarks**
	pollutants in three dimensions. MOTHY is an integrated system that includes hydrodynamic coastal ocean modeling and real time atmospheric parameters from a global model. The oil slick is modeled as a distribution of independent droplets that move in response to currents, turbulence, and buoyancy.		
2. The GNOME model and subsequent trajectory analyses were used during a recent event off San Francisco, oil removal operations from the wreck SS Jacob Luckenbach. The Luckenbach is a C-3 cargo ship that sank 17 nm southwest of the Golden Gate in about 180 feet of water in 1953. This vessel was fully laden with fuel and cargo and had just left port en route to Korea to bring supplies for the war effort. Broken into two pieces on the bottom, this vessel was	GNOME Model: **The latest iteration of** NOAA FIAZMAT's **oil trajectory model is** GNOME: **General** NOAA Oil **Modeling Environment. GNOME simulates the movement of spilled oil from local currents, winds, tides, spreading and other physical processes.** To continue with model **initialization,** users input wind data either from their own file or through	Spill size, type, location, time of occurrence. localized current, wind and other environmental parameters like temperature, seasonal factors and diurnal effects.	It is clear that trajectory models can be a powerful tool in the response and planning toolbox, it is essential to understand and work within their numerous limitations. Model products can he developed specifically for an incident, tailored to the particular issues and objectives of concern. This type of risk assessment gives responders an ability to plan for how quickly they will need to initiate mitigation procedures before these sensitive resources could be impacted from a release from a spill. The flexibility and creative thinking concerning real time dynamic situation and factor that resulted in such new type of spill response tool is a key factor in the success of any spill response.

Description of Incident- Accident	Description of Model	Parameters considered	Remarks
discovered recently to have been episodically leaking unknown quantities of bunker fuel oil into the surrounding highly vulnerable area, and impacting thousands of seabirds, shore birds and miles of coastline habitat. United States Coast Guard (USCG) and California Department of Fish and Game's Office of Spill Prevention and Response (OSPR), hired a salvage contractor in May 2002 to assess the amount of oil still left on board the vessel and determine how best to remove it.	published wind tools. Once the environmental parameters are initialized, the next step is to specify the spill details including date, time and location of the spill as well as pollutant type. Users are then directed to a map window that will display their area of concern and their incident specific information. The model is then run for a specified length of time, creating a movie of frames, showing the path of the oil spill at individual time steps. At this level of the model, the oil slick is represented by a collection of particles. Each of these particles has the ability to account for spreading and weathering of the slick as it moves through the marine environment, affected		

Description of Incident - Accident	Description of Model	Parameters considered	Remarks
	by wind and seas. Some of these particles may evaporate over the model run time, some may disperse naturally and some may beach – depending on the product type and spill-specific parameters.		

General Analysis: NUMERICAL MODELLING OF THE BEHAVIOUR AND EVOLUTION OF 01L SPILLS AT SEA:

Spreading and weathering processes (i.e. evaporation, dissolution, dispersion into the water column, emulsification. changes in viscosity and density) can be simulated by numerical models based on mathematical formulations that describe these processes, according to their physical and chemical properties. It is important to keep in mind that the numerical model to be used should be sufficiently simple and fast, from a computational point of view, to allow information to be gathered in real time, and for the following reasons:

- the evolution of hydrocarbon spills depends on environmental processes and factors that are still poorly understood and whose mathematical description is complicated, and depends on more or Icss empirical hypotheses;
- in real accident cases, important factors are generally unknown. such as the real quantity of oil spilt and sonic of its properties.

In preventive terms, these models could even be the only method of planning the implementation of means of combating pollution at sea. In the meantime, predictions provided by the numerical models should whenever possible, be accompanied by direct observations. In this way, the model's predictions will help to guide direct observations, and, with the necessary precautions, direct observation will permit the recalculation of prediction data from that point on.

7.5 Discussion and Conclusion

The comparative statement of use of models for assessment of risk shows that in all cases similar mathematical model programmed and written in FORTIRAN and the graphic interface program for input and output are written in VISUAL BASIC. The model can forecast the distribution of spilled oil ahead of 2 weeks in a few minutes and can work in PC with CPU: Pentium 3 or more than 650Mhz, Main Memory: 128-256 MB, I lard disk: I-l0 GB (AS VIRTUAL MEMORY), Display resolution: 1024x768 dot.

The accuracy of out put data is dependable on the correctness and reliability of various input data including Meteorological. Hydrological and f:lectronic Nautical Chart. It is necessary to work with updated information and data to minimize errors.

In this study for the dissertation, a two dimensional demonstrative oil spill has been shown with case studies for the Pussur River, to create example to follow the process for other areas with different parameters in real time and practical case of incident(s). This will enable to analyze impacts of oil spill accidents for some possible scenarios and prepare strategy planning assessment.

Such model can calculate the distribution of spilled oil on surface through physical process like advection, diffusion and spreading, the change of oil volume and property of the oil through chemical process like evaporation, dissolution and emulsification. The obtained results of trials can be used for counter measures, the risk assessment at the time of the oil spill accident. In the study as mentioned in earlier sections about the effect of oil, its type and accumulation and settlement on plants and mangroves. So the total findings may be combined for total impact assessment and risk associated there of.

The study **model has been** applied to test five case studies to prepare information for the contingency **plan and clean up operation.**

Through the case studies, it is found that the difference of the wind between dry season and flood season makes much difference of oil position. In dry season the spilled oil may reach the Bay of Bengal in two weeks even spill point is upstream of Monkey Point because the southward wind push the oil to downstream side. While, in flood season the oil may not move far downstream from spill point because the northward wind push the oil upstream against southward flow.

Simulation for risk assessment of coastal area should realize the real marine environment. It is required the scientific operation. In order to do that, numerical models and reality modeling techniques are essential. These are related to spatial information so spatial database in simulation is the key element. I-Iowever. various data formats and resolutions cause building simulation database to be very complex and difficult. And there is no specialized software for building spatial database for simulation.

Despite GIS technology has been developed, various spatial datascts have some problem related with consistency. These problems include different gird size, different scale. different dates of production and so on. They make building database for simulation to be complex and hard. In order to solve these problems, making the strategy and plan for building consistent spatial database.

At first step of GIS, spatial objects were represented as the 21) simple features like a point, a line and polygon. And they were stored in simple data format. As database management technology is developed, spatial objects have been represented as complex and real features with various topology and symbology. More complex and heavy objects cause data storage method to be the database driven method. GUS has been developed with database technology.

Since processing the complex and huge database in GIS is possible. the demands for advanced simulation in GIS are stronger than any other past years. Virtual Reality (VR) and marine models have become the important elements in simulation. In order to improve the quality of the simulation, precise marine models should he developed and integrate with GIS. GIS technology may be a new tryout in maritime VR simulation works.

Advanced **spatial database** driven **simulation** would he necessary. Many **studies and** tryout would be **required**. **In the near feature, marine** spatial database **infrastructure will be essential element in marine simulation** and it should integrate many **numerical models** and VR objects.

7.6 Recommendation

In this study, a demonstrative oil spill has been considered and discussed as an example and guideline map to understand the whole process of risk assessment of oil spill related accidents so as, as the first step to cope up the Future oil spill accidents in Bangladesh. However, this is not a real-time response model. The model is needed to step up for the final goal. As such some recommendations are suggested about oil spill model as follows:

(iii) Model should be updated for dynamic condition with current bathymetric and hydrological data.

The model as discussed and considered in this study based on the hydrological data of the Pussur River for 1998-2000. If oil spill accidents happen today. up to date bathymetric

data and hydrological data of at least the previous month from the day of oil spill accident are to be considered.

(iv) Forecasted wind data is required for real-time model.

The wind has influence on the drifting surface oil. For predicting the oil position. the forecasted wind data for 2 weeks after oil spill accident is needed. In Bangladesh the forecasted wind data has not been provided on line from meteorological department yet. In this study, wind data of 1998 has been considered.

(v) The oil **spill model should be extended** for risk **assessment of further areas of ¡mpacts for national contingency plan.**

(vi) Chittagong Port Area

The Pussur River oil spill model was developed against the oil spill accidents in Sundarban mangrove forest with concern for environmental damages.

With respect of the risk of oil spill, the Chittagong Port area also has been growing the potential causing oil spill accidents from a number of oil tankers, an oil refinery, the oil terminal berth, movement of tankers laden with oil and large ship breaking industry. Therefore, the oil spill model for the Chittagong Port area needs to he developed as well.

(vii) Bay of Bengal

According to the results of some case studies, the spilled oil at Monkey Point in dry season can reach off shore in the Bay of Bengal within 2 weeks. 1 he oil off shore may move along the ocean current and may hit the coast in neighboring countries and vice versa. For the counter measure against such off shore oil spill, the model embedded ocean current data and off shore wind data should be developed analyzing and using satellite sensing data.

Chapter 8: **Findings, Recommendations** and Conclusion

8.1 Findings and Present Scenario

Since no major incident of oil spill occurred at recent time in Bangladesh water nor was there any wide scale operation of response due to sporadic small scale incidents mainly due to maritime operations of routine nature, approach to collect available information from different govt. agencies including Chttagong Port Authority, Bangladesh Shipping Corporation, Department of Shipping and Department of Environment was made in addition to exploring websitcs of innumerable related publications using internet. held discussion with concerned officials of the stated organizations and also visited their libraries to collect information which made this paper fact based and enriching knowledge for further in depth analysis in course of the study.

1. Hundreds of ships visiting Bangladesh's main port in Chittagong are taking advantage of lax laws and logistic backups against dumping of pollutants into the sea with officials struggling to stop it with only a pair of binoculars and camera in most of the cases.
2. Situation in Mongla port is worse as the port lacks even the minimum manpower requirement to patrol the area. Fortunately, frequency of traffic there is much less in comparison to Chittagong.
3. Many foreign ships continue to use to dump burned oil in the outer anchorage of the ports defying international regulations though few sporadic vigilance and mobile court actions could limit very few violations and attempts.
4. Neither of the ports have any receiving facilities of wastes for disposal from ships.
5. The most alarming issue of the whole scenario o1 oil spillage is that taking the advantage of weaknesses of the port authorities and poor laws and their lax implementation due to inadequate logistic support, the foreign and even local ships find Bangladesh ports and its' outer anchorage as safe dumping areas of their waste.

6. The port authorities although have been able to detect about 700 offending vessels over the last three years and lined them but the damages that was caused to affected waters was very negligible and in no way comparable to fines imposed.
7. The saddest part of the issue of pollution of Bangladesh coastal waters due to oil spill from ships is the lack of required laws and regulations and lax of implementation of the existing laws giving full advantage to foreign ships calling Bangladesh.
8. The foreign ships calling Bangladesh ports coming from ports of Singapore, Malaysia, Sri Lanka and even India, discharge dump their pollutants in Bangladesh waters taking advantages.
9. Any other international port would have imposed heavy penalties or even seized and blacklisted ships if found violated marine laws or polluted the sea.
10. It is also the reluctance from the part of our Govt. to understand and requirement to timely ratify international laws and conventions to protect country's own interest. Non ratification of related international laws and conventions put the country in weaker position to take legal actions against the violators who knowingly take the Bill advantage stated above.
11. At present there is no National Oil Spill Contingency Plant for the country.

8.2 Recommendations

Natural disasters have become a pert of life of Bangladesh and its vast population of about 150 million residing in a limited area of approximately 148.000 square kilometers. Couple with the threat of the Climate Change squeezing livable area further and vulnerability to added flood and tropical cyclones and storm surge intensities put the country to prepare and adopt itself with utmost care and sincerity and without wasting valuable time to address the burning issues.

The coast of Bangladesh is a zone which remains under ofinultiple vulnerabilities and at the same time gives enormous opportunities for its richness of natural resources. In combination with the natural hazards, various forms of man made hazards like pollution and continuous oil spills from ships in the region put the coastal dwellers to further vulnerability slowing down their socio-economic development.

Absence of facility to treat wastes is another cause of pollution. About three thousand five hundred ships including crude oil tankers calling our ports every year in addition to another few thousand inland vessels portion of which also plying through coastal waters spill oil. Top of that the threat of accidental oil spillage from the crude oil carriers pose severe threat to pollution and disaster to coastal water.

This study will therefore, seek to analyze the vulnerahilities and risk of coastal water and suggest adopting appropriate measures for mitigation and management of coastal environmental pollution to the extent of generating awareness among the population and authorities ofthe threat of consequences ofthe related disasters.

The areas of recommendation may be summarized as lollows:

1. Put urgent emphasis to review the legal and regulatory instruments and standards in place for dealing with oil spills and ship originated pollution.
2. Address port and shipping related environmental management issues, particularly in relation to adoption of international conventions.
3. Chittagong Port and Mongla Port to have reception facilities for disposal of ship borne waste.
4. National Instruments to examine with urgency and carefully with respect to strengthening Chittagong Port Authority (('PA) and Mongla Port Authority (MPA) for effective mitigation, monitoring, and enforcement of appropriate regulations as well as the preparation and efficient implementation of National Oil Spill Contingency Plan.
5. Develop foundation and basis of a national Oil Spill Contingency Plan that will provide the legal and regulatory framework for oil spill response mechanisms for ports in Bangladesh.
6. Establish effective monitoring arrangements for environmental impacts in all port areas.
7. Introduce monitoring and risk assessment systems to identify the risks of contamination and pollution related hazards and disasters.

8. Establish areas of jurisdiction of the Port Authorities and Bangladesh Coast Guard.
9. Equip both the ports with necessary vessels, equipments and other resources to respond to accidental large scale oil spill from ships.
10. Provide adequate patrol boat and aids for surveillance.
11. Coast Guard to provide with aircrafts and high speed boats 1Or patrol
12. Obtain International support in terms of technology. experience and finance will be essential as domestic resources and capacities are limited.
13. Govt. instrument to pursue finalization of the draft of Regional Oil and Chemical Pollution Contingency Plan for South Asian countries comprising Bangladesh, India, the Maldives, Pakistan and Sri Lanka.
14. Pursue to implement the Regional Contingency Plan as early as possible and increase regional cooperation for mutual benefits.
15. In the context of socio-economic scenario of Bangladesh- the country has no other alternative than to enter into post-disaster phase of socio-economic recovery and reconstruction and face the longer-term issue of disaster reduction through risk management which also indicates that international support as stated above that Bangladesh will require in future years to achieve the objective, and
16. Finally create awareness among the people and govt. instruments and agencies about the hazard of marine pollution and consequences of disaster of accidental oil spillage from ships in Bangladesh waters and in the region which will help us to prepare the country to mitigate and respond against possible risks.

S.3 Conclusion

From the information gathered and roughly analyzed so fuir including the surveys in the field carried out by Japan Oil Engineering Co., Ltd.. Japan in association with Fuyo Ocean Development & Engineering Co.. I.td.. Japan, it can be said that the situation of oil spill in Bangladesh as a matter of comparison is probably worse than that of Japan, even though, Japan consumes more than sixty times more of oil compared with Bangladesh. Where as industrial discharge of oil content and preventing facilities and mechanism and administrative preparedness in Japan are more severe, stringent and organized than Bangladesh. Absence of required facilities, weak enforcement of available regulations and lack of initiatives and seriousness to address the issues of hazards of oil spill has put Bangladesh to a worrying stage and with the increasing oil consumption in line with the country's development and economic growth, is bound to assume more serious proportions. Therefore, at this point of time, proper risk assessment, control and management system for oil spill in Bangladesh and neighboring region has to be given due priority by providing a regulatory framework as well as preparing a contingency plan for mitigation. preparedness and response against the hazards of oil spill and impact of the disaster.

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