UNIVERSITI
TEKNOLOGI
PETRONAS

RISK ASSESSMENT OF PIPELINE LEAK USING GEOGRAPHIC INFORMATION SYSTEM (GIS)

By

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FINAL YEAR PROJECT REPORT

Submitted to the Civil Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Civil Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

Dr. Abd Nasir Matori,
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UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2006

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Mohd. Azza Bin Zaini

ABSTRACT

This paper is discussed about the utility of GIS technology to enhance the Oil Spill Risk Management System (OSRMS). In this system, the oil spill information, access and also the protection data is needed to be analyzed with the relational database. This database will give the information about the rapid access, retrieval and query. This GIS is providing Malaysia's coastal area information such as the location of oil spills, pipeline location as well as quantity of oil spill area and distribution in area affected; area with heaviest contamination, and also the length of the shoreline. An oil slick movement model was incorporated into this system in order to predict the oil slick movement direction and the duration to reach the shoreline. Wind and current are the main parameter for this study. This GIS-based system can be used to replace typical way in order to establish appropriate response and locate the intense area in slick and local supervision, to allow clean up vessel to detect the specified location and begin the cleaning operation immediately. This management system will offer a better multiple resources planning with a new approach, improve decision making process, and provide a baseline for future assessments.

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CHAPTER 1
INTRODUCTION

Recently, management of health, safety and environmental protection (HSE) became an important subject for the design and construction of marine structures. The objective of design projects is to engineer safe, robust and operable structural systems at minimum life cycle cost. The HSE target is to have an injury/illness free work place in the design and construction process. Some of the other important subjects in HSE are for instance, emergency response, evacuation escape and rescue, fire protection and medical response. From the view of the environmental protection, the leakage of hydrocarbon from pipelines and risers, tankers and facilities shall meet the required standard.

1.1 Background Study

For the completion of the project, knowledge on the application of GIS software (Map info), oil pollution, coastal environmental component, fluids properties, Hydraulics, Offshore and Coastal Engineering. These subjects under discussion will serve as the fundamentals in understanding the essential theoretical concepts and act as guidance in learning the best approach for the project

1.2 Problem statement

Many of Petronas Carigali Sabah Operation (PCSB) pipeline are over 20 years old and hence have the significant chance to leak/burst, which could have serious impact on environment. Incidents due to intentional or intentional occurred in Malaysia water has increased over the year.

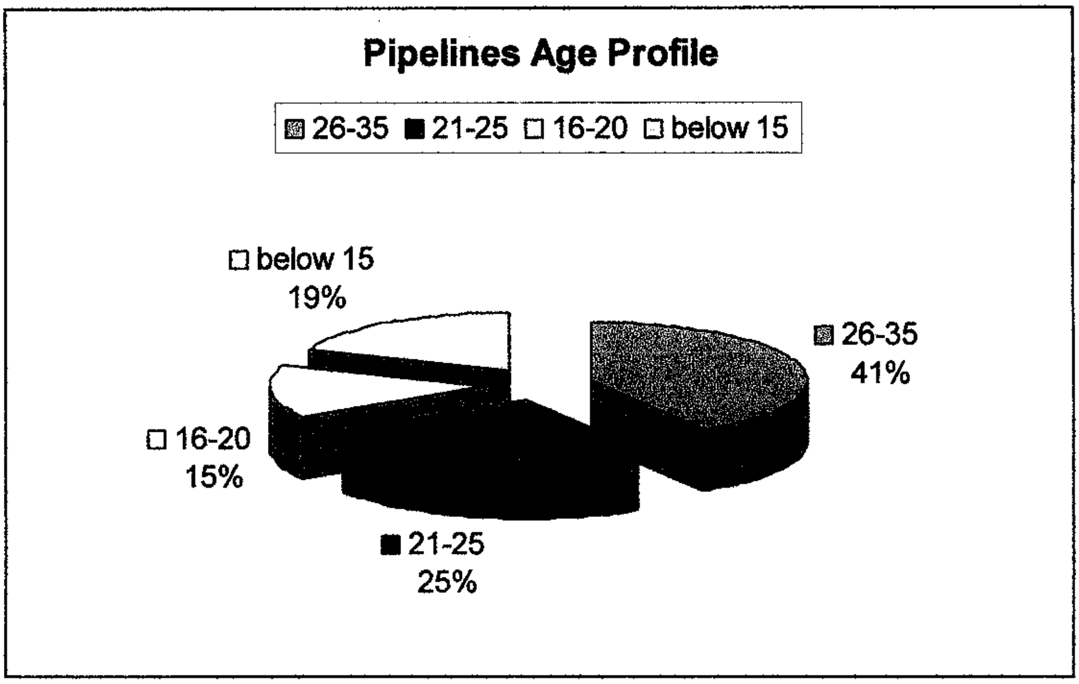

Figure 1 SBO pipeline Age Profile

The major source of oil spills occurred are from oil production at offshore, tanker accidents and pipeline leakage as stated in DOE (Department of Environment) Report, (1995)[1].

Therefore if the risk of the pipeline could be modeled/predicted/forecasted, necessary action of plan could be prepared to mitigate and /or reduce the impact of the leak. The risk assessment is quite impossible to be carried out manually. However, it could be carried out using spatial data analysis in GIS.

1.3 Objectives and scope of study

This part will be basic fundamental in what are going to turn out throughout the study period.

1.3.1 Objectives

- To forecast risk and impact of pipeline leak to environment
- To produced GIS application for risk assessment analysis
- To integrate pipeline data into the GIS application

1.3.2 Scope of Study

This final year project cover on software application and environmental aspect related to oil pollution. Some study was also done on Oil Spill Risk management System and oil spill trajectory modeling or oil slick modeling. An oil slick modeling was used in order to study the oil properties and the behavior of oil on water surface. The oil slick movement direction can be determined by using some basic parameter. Wind and current are the main parameter for this model. Appropriate response studies have to be carried out and integrated to the management system in order to improve decision making process.

CHAPTER 2
LITERATURE REVIEW AND THEORY

2.1 RISK ASSESSMENT

Risk assessment is more and more applied in managing safety, environmental and business risk. Figure 2 shows basic procedures for the risk assessment.

A risk assessment is a careful examination of work environment that could cause harm to people, so that firm can weigh up whether there have taken enough precautions or some prevention should be taken appropriately. The aim is to make sure that no one gets hurt or becomes ill. Accidents and ill health can ruin lives, and affect overall business if the output is pollution, lost; machinery is damaged, insurance costs increase, or even penalties. The important things before risk assessment is carried out, we need to decide whether the hazard is significant, and an adequate precaution is already in place.

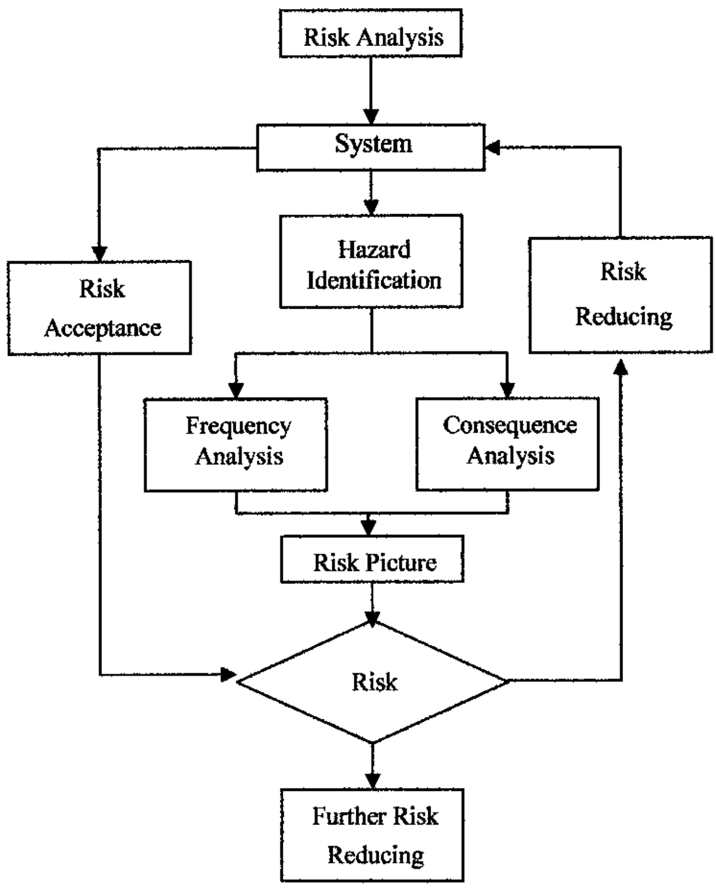

Figure 2 Basic procedures for the risk assessment

2.2 Properties of Oil

Crude oils of different origin vary widely in their physical and chemical properties, whereas many refined products tend to have well-defined properties irrespective of the crude oil from which they are derived. Residual products such as intermediate and heavy fuel oils, which contain varying proportions of non-refined components blended with lighter refined components, also vary considerably in their properties.

The main physical properties which affect the behavior and the persistence of an oil spilled at sea are specific gravity, distillation characteristics, viscosity and pour point. All are dependent on chemical composition (e.g. the amount of asphaltenes, resins and waxes which the oil contains).

Specific gravity or relative density of oil is its density in relation to pure water. Most oils have a specific gravity below 1 and are lighter than sea water which has a specific gravity of about 1.025. The American Petroleum Institute gravity scale °API is commonly used to describe the specific gravity of crude oils and petroleum products, and is calculated as follows:

$$°API = \frac{141.5}{specific\ gravity} - 131.5$$

In addition to determining whether or not the oil will float, the specific gravity can also give a general indication of other properties of the oil. For example, oils with a low specific gravity (high °API) tend to contain a high proportion of volatile components and to be of low viscosity.

Distillation characteristics of oil describe its volatility. As the temperature of oil is raised, different components reach their boiling point one after another and evaporate, i.e. are distilled. The distillation characteristics are expressed as the proportions of the parent oil which distil within given temperature ranges. Some oils contain bituminous, waxy or asphaltenic residues which do not readily distil, even at high temperatures. These are likely to persist for extended periods in the environment.

Viscosity of oil is its resistance to flow. High viscosity oils do not flow as easily as those with lower viscosity. All oils become more viscous (i.e. flow less readily) as their temperature falls, some more than others depending on their composition. Since sea temperatures are often lower than cargo or bunker temperatures on board a vessel, viscosity-dependent clean-up operations such as skimming and pumping generally become more difficult as the spilled oil cools. The temperature-viscosity relationships for three crude oils are shown in Table 1 and Figure 1. In this paper, units of kinematics viscosity, expressed as centistokes (cSt) are used.

Pour point is the temperature below which oil will not flow. The pour point is a function of the wax and asphaltene content of the oil. As an oil cools, it will reach a temperature, the so-called 'cloud point', at which the wax components begin to form crystalline structures. This increasingly hinders flow of the oil until it eventually changes from liquid to semi-solid at the pour point. An example of this behavior is shown for Bonny Light in Figure 1 and Table 1. For this oil, as it cools from a typical cargo temperature of >30°C, its viscosity rises slowly, but below 20°C it begins to thicken exponentially until at around 12°C the viscosity has increased so much that it will no longer flow. For the other two oils shown, the pour points and cloud points are below 0°C.

2.3 Oil Spill Trajectory Model

A simple linear oil spill trajectory model was customized into the GIS environment. The velocity and direction of winds and currents are the parameters. An oil slick always be under influence of both parameters, hence the present drift prediction is based on these combined effects.

Oil slick movement = 0.033 Wind + 0.56 Current

$$V = 0.33V_w + 0.56V_c \text{ [2]}$$

The evaluation of the direction and magnitude of the resultant force of wind and current acting on an oil slick utilized information on the direction, and velocity (**Vw**) of the average monthly wind as well as the direction, and velocity (**Vc**) of the prevailing currents.

These trajectories are used to generate probabilities that water surface and shoreline areas will be oiled by a release from the given site. Practical use for such information includes the determination where response equipment should be placed to be most effective.

The subsurface model tracks both the surface and subsurface movement of oil. The oil's distribution in various environmental compartments (water surface, atmosphere, water column, and shoreline) is determined. Oil that is entrained into the water column by breaking waves (due to wind energy) is tracked and displayed. Oil that may resurface is also included.

2.4 SAMARANG - LCOT Pipeline Incident

Petronas Carigali Sabah Operation (SBO) is currently operating 53 pipelines with a total length of approximately 420 KM. The 18" SMR-A to Labuan Crude Oil Terminal (LCOT, operated by SSPC) pipeline (PL144), 47.7 km length, serves as an export trunkline for Samarang and Kinabalu fields to LCOT.

PL144 is a common facility under Sabah Global Sharing Agreement (GOSA) shared between Samarang Asam Paya PSC and SB1 PSC. It was installed in 1974 and operated by Sabah Shell Petroleum Company (SSPC). Subsequently, it was handed over to PCSB in April 1995. In 1997, Kinabalu field (operated by SSPC) was tied-in to Samarang which increased the production from 30,000 to 70,000 bpd (gross).

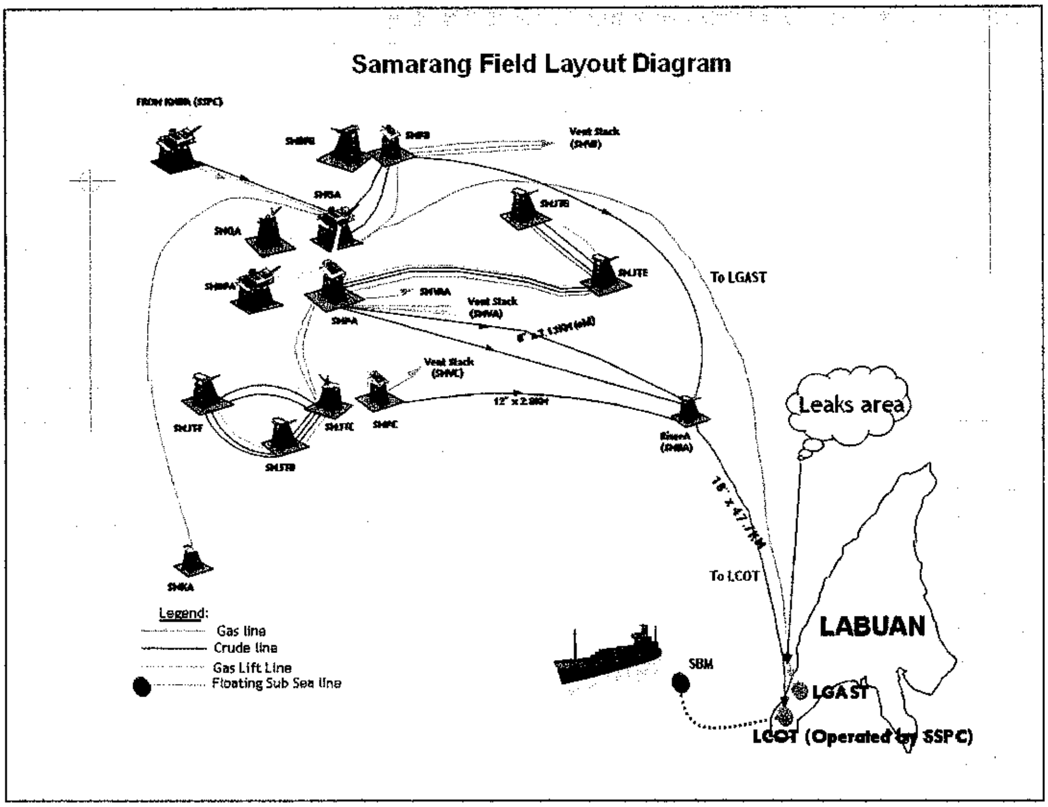

Figure 3 Pipeline Leakage Location

2.4.1 Incident Summary

- Date: 18 Oct 2004
- Location of incident : South-west offshore Labuan on the 18" PL 144 pipeline connecting LCOT and Samarang Riser platform
- Total no of leak points: 4 nos (between 1.81 to 2.24 km from LCOT)
- Total estimated spill volume : 100 bbls
- Affected beach areas : 1.3 km of the Kiamsam beach (between LCOT and UMS) and Kuraman Island
- Total clean-up days : 21 days (ECC stand down on 7 Nov 2004)

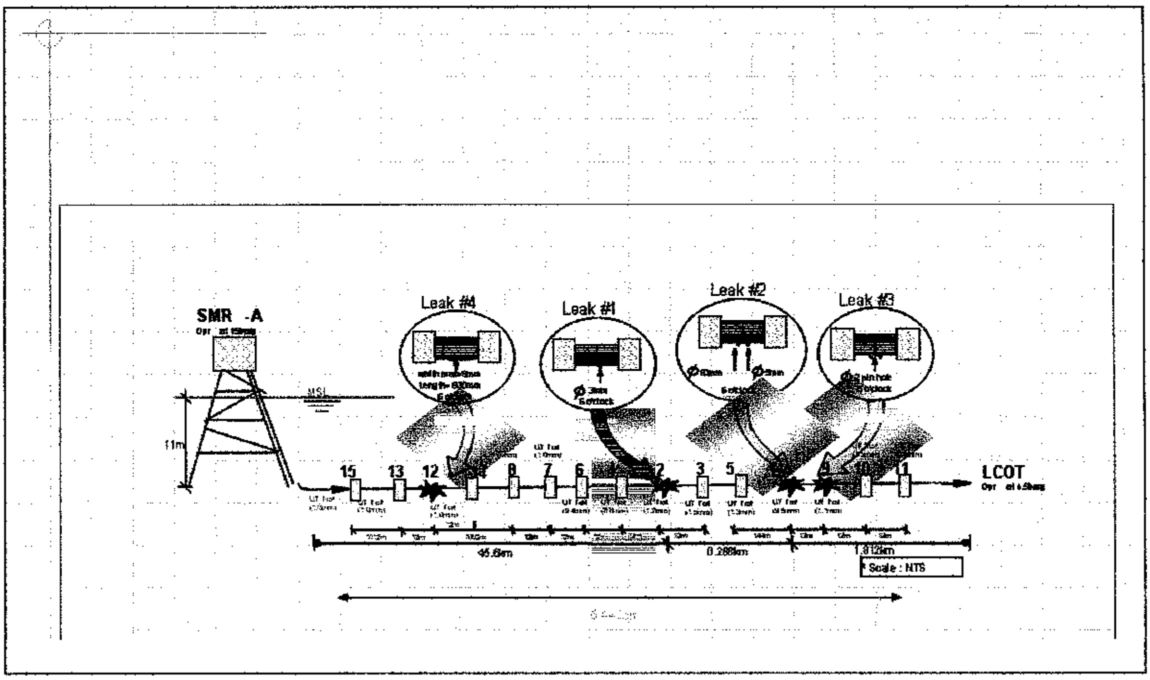

Figure 4 Leak locations

2.4.2 Pipeline Leak

- The faulty closure of SDV (Shutdown Valve) due to loss of instrument air system at LCOT has resulted in pressure surge up to 28 barg in the pipeline which exceeded MAOP of 13 barg.

- Insufficient internal corrosion monitoring and mitigation activities, coupled with presence of Sulphate Reducing Bacteria (SRB) may have increased the number of metal loss defects from 15,000 (average defect depth 30%) in 2003 to 300,000 (average defect depth 70%) in 2004

- Contradicting statement in Fitness For Service (FFS) report by 3rd party performed in 2003. Executive summary mentioned that the pipeline is fit for use until 2030 but interacting defect analysis in the appendix of the report showed that pressure containment capacity in several sections of pipeline is zero.

CHAPTER 3
METHODOLOGY

3.1 Procedures

In order to ensure this project is accomplished successfully, procedures are developed as a pathway all the way through end of study. There are mainly researches, data gathering and at the end a GIS application is develop to simulate the result.

3.1.1 Research

The author has to do an in-depth research on oil spill impact to coastal environment and how to utilize GIS application in order to predict the possible impact and area covered by the pollution. Research also must be done in risk analysis management in order to classify the severity of the impact. The author must also know the basic ecology system involved in coastal area.

3.1.2 Data gathering

After understanding the concept, the author must gather the information from related party. Information is related to map for study area, environmental elements and risk assessment management approach to solve water pollution problems.

3.1.3 Developing a GIS application

The data gathered if compile and arrange properly and the author will began to construct part by part and again analysis is conducted to simulate the incident in spatial data.

3.2 Tools Required

There are some tools that are usually utilized all through the procedures. There are as follows.

3.2.1 MapInfo software

Map info software v7.0 is same with the other GIS applications that is used to present map in GIS approach.

3.2.2 Auto Cad 2004

This software purposely used as drawing tools.

3.2.3 Oil on Water Trajectory Calculator

It is used to estimate distances, time traveling and speed of oil under wind and current factor.

CHAPTER 4
PIPELINE RISK ASSESSMENT

Risk assessment can be done in two approaches. The first is a relative risk assessment using scoring approach that compares the probability of failure for different segments of the overall pipeline and the uses these scores in the context of an impacts assessment describe in potential impact assessment. This allows the setting of priorities for mitigation of spills. The second part is a probabilistic risk assessment that allows the comparison of the risk at specific location with other societal risks. This will provide a comparative context for making risk based decisions on the pipeline's operation.

4.1 Pipeline Hazards

As required in the Settlement, transport hazards of crude oil and refined petroleum products were examined. These hazards were identified and used as input data for the risk assessments in the impact analyses, where crude oil and refined product impacts are compared. The primary hazards of transporting petroleum products and crude oil arise from flammability and toxicity in the event of leaks and spills. Flammability contributes primarily to safety concerns and toxicity to environmental concerns; however, a fire can also, for example, endanger threatened species or damage archaeological and historic sites.

4.2 Leak and repair history

An additional assumption concerns the use of previous fault indications. For modeling purposes, previous fault indications such as leaks, repairs, and internal line inspection (ILI) indications are considered evidence of increased susceptibility to failure. A "zone-of-influence" is assumed and all pipes within that zone are similarly shown to have increased risk. The existence of a leak or other fault therefore "penalizes" several hundred feet of pipe in the model, depending on the type of leak or fault. This is determined by the statement that failure mechanisms can extend to some distance from the actual event. This is conventional, since most faults are from limited to a small area initiator that has been permanently repaired. However, such previous indications also show that conditions were contributing to deterioration and failure, at least at one time. Even after a repair, the model conservatively assumes that the basic failure mechanism still be there. The consequence can be removed if a formal root cause analysis is done and the conditions are permanently changed so that the fault initiator is not a risk. For these purposes, a *root cause analysis* is a thorough investigation that conclusively identifies the chain of events leading to the failure and indicates the primary mechanism which should be addressed to prevent any future such failures.

4.3 Product Properties and Spills

Crude oil and refined products are mixtures of many organic compounds. They are complex materials, but are not usually subjected to detailed chemical analyses during refining processes or when used in common commercial applications. These products are usually characterized by a set of key physical properties. The composition of the transported product affects flammability and toxicity as well as flow, dispersion, and persistence properties in the environment. In comparing the risks of the transporting refined products and crude oil, the relative properties of crude oil and refined products are a significant factor.

4.4 Spill Volumes

Potential spill quantities of refined products were estimated at several sensitive locations along the pipeline. The size of a leak is dependent upon the size of the opening in the pipe, the product density, the pipeline pressure, topography, and duration. The estimated release volumes consist of (a) the volume released during the time it takes to detect the leak and shut down the pipeline, plus (b) the maximum volume that can drain from the pipeline segments upstream and downstream of the leak site.

4.4.1 Hole Size

In assessing potential hole sizes, the failure mechanism and pipe material properties must be considered. A failure mechanism such as corrosion is characterized by a slow removal of metal and hence is generally horizontal to produce pinhole-type leaks rather than large openings. Outside forces, especially when cracking of the metal is precipitated, can cause much larger openings. The size of the opening is a function of many factors including stress levels and material properties such as ductility. Since there are so many variations of factors possible, hole sizes can be highly variable. However, the opening size is at least partly dependent upon the initiating failure mechanism. The Environmental Assessment (EA) does not attempt to make correlations between failure mechanisms and leak sizes. Conservative (i.e., reasonable worst case) leak size assumptions, regardless of mechanism, are used by assuming complete pipeline rupture where the hole size is effectively the pipe diameter.

CHAPTER 5
RESULTS

5.1 Pipeline Drawing

Basic drawing was performed by using AutoCAD before it is transfer to MapInfo format.

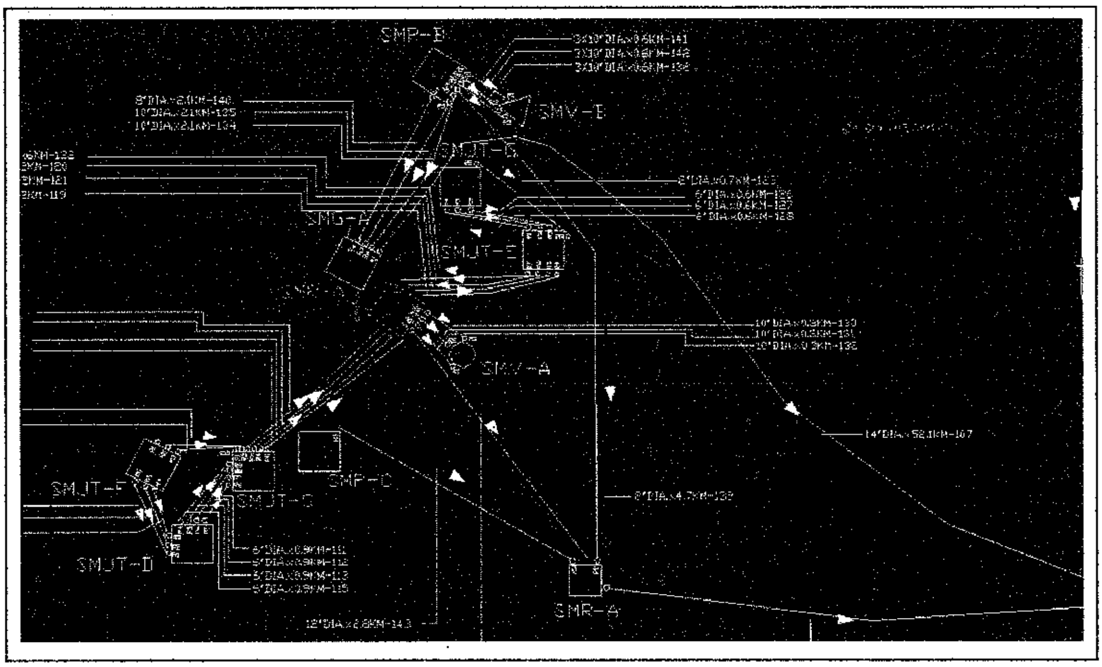

Figure 5 Samarang Pipeline Network (Petronas Carigali SBO)

5.1.1 MapInfo Mapping

This is the study area, mainly located at Malaysia shoreline.

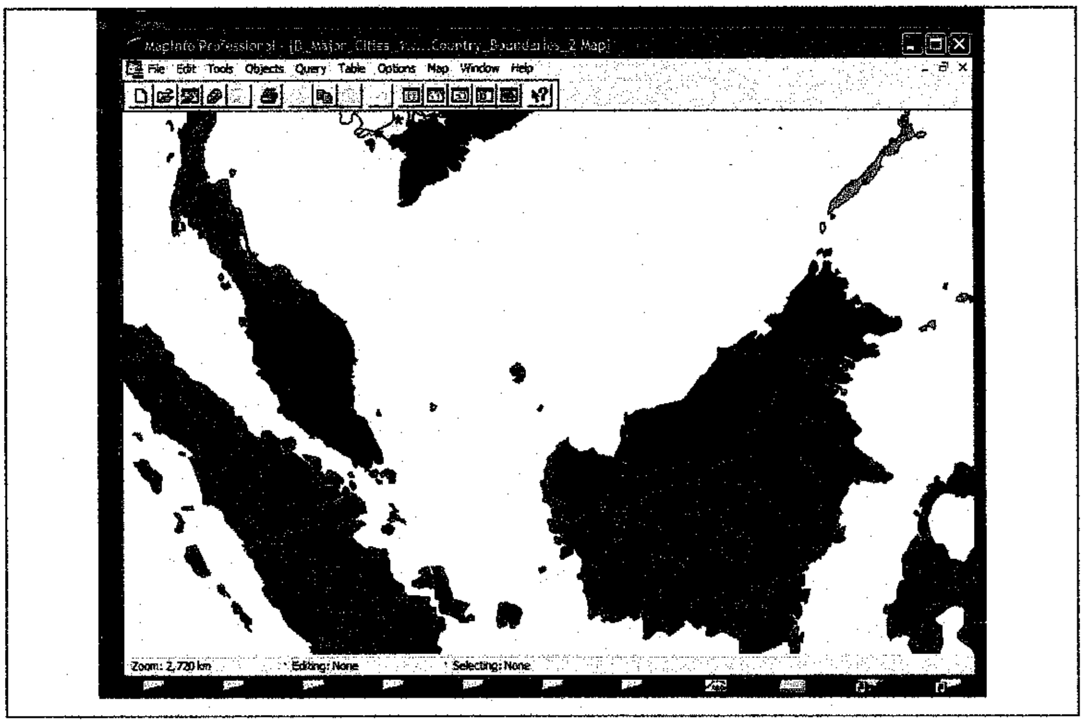

Figure 6 Study area – South China Sea

5.2 Oil trajectory analysis

The analysis part is done by using software application used by Spill Training Company namely Oil on Water TRAJECTORY CALCULATOR. Parameter such as wind and current are used to predict the distances and the location of the oil drift. Data of wind speed and direction have to be key-in followed by Beaufort wind force data.

Current Speed (Vc) m/s	Average Speed (m/s)
South China Sea	
0.3 - 1.1	0.70

Table 1 Current Speed at South China Sea

Wind Speed (Vw)		(m/s)
Peninsular Malaysia	NE 20-30 km/hr	5.56-8.33
Sarawak	NE 20-30 km/hr	5.56-8.33
Sabah	NE 20-30 km/hr	5.56-8.33

Table 2 Wind Speed

5.2.1 Oil slick movement Analysis

Oil slick movement = 0.033 Wind + 0.56 Current

V = 0.33Vw + 0.56Vc [2]

Vw (m/s)	Average Vc	V
5.00	0.70	2.04
5.10	0.70	2.08
5.20	0.70	2.11
5.30	0.70	2.14
5.40	0.70	2.17
5.50	0.70	2.21
5.60	0.70	2.24
5.70	0.70	2.27
5.80	0.70	2.31
5.90	0.70	2.34
6.00	0.70	2.37
6.10	0.70	2.41
6.20	0.70	2.44
6.30	0.70	2.47
6.40	0.70	2.50
6.50	0.70	2.54
6.60	0.70	2.57

Vw (m/s)	Average Vc	V
6.70	0.70	2.60
6.80	0.70	2.64
6.90	0.70	2.67
7.00	0.70	2.70
7.10	0.70	2.74
7.20	0.70	2.77
7.30	0.70	2.80
7.40	0.70	2.83
7.50	0.70	2.87
7.60	0.70	2.90
7.70	0.70	2.93
7.80	0.70	2.97
7.90	0.70	3.00
8.00	0.70	3.03
8.10	0.70	3.07
8.20	0.70	3.10
8.30	0.70	3.13
8.40	0.70	3.16

Table 3 Trend of oil trajectory speed

5.3 Oil on Water Trajectory Calculator

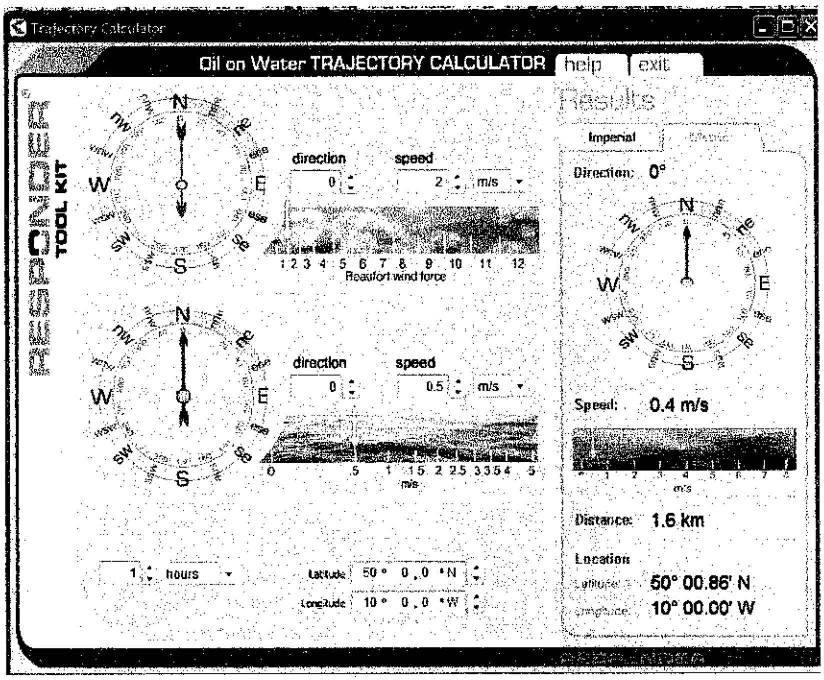

Figure 7 Oil on Water TRAJECTORY CALCULATOR

Wind		Current		Results	
Speed (m/s)	Direction(°)	Speed (m/s)	Direction(°)	Distance(km)	Speed (m/s)
1.0	270	0.5	90	19.1	0.5
1.5	270	1.0	90	37.6	1.0
2.0	270	1.5	90	56.2	1.6

Table 4 Result of oil trajectory by using TRAJECTORY CALCULATOR

5.4 Scenario 1

One location is created as study area, where oil spill predicted to happen at middle span of the pipeline. The pipeline identity is PL144 LCOT to SMR-A platform. The spill begins at location 24 KM from LCOT onshore terminal that is located in Wilayah Persekutuan Labuan.

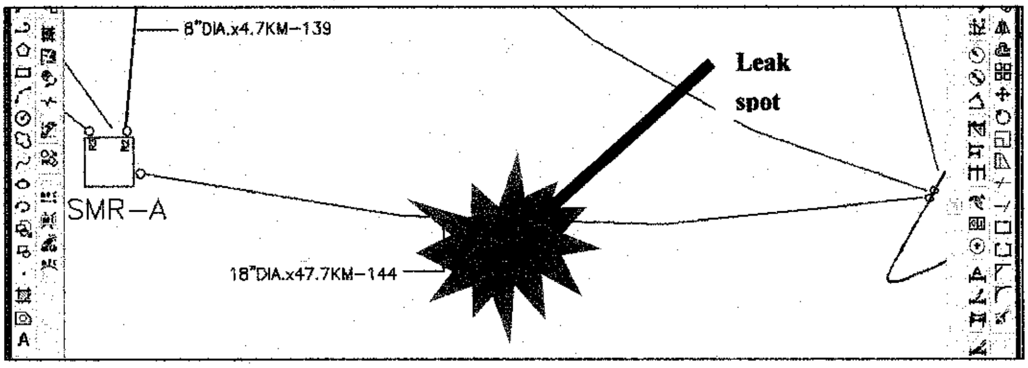

Figure 8 Location of leakage

According to data provide by Sabah Government Department of Environmental, a study of oil trajectory has been carried out. Oil on water Trajectory Calculator is used to calculate the results.

Data to calculate the trend:

Wind direction: 45°

Wind Speed = 5.56 m/s

Current direction: 45°

Current speed = 0.7 m/s

RESULTS		
Duration(hr)	Speed (m/s)	Distance (km)
16	0.5	30.7
24	0.5	46.1
36	0.5	69.1
48	0.5	92.2
56	0.5	107.5
64	0.5	122.8
72	0.5	138.2

Table 5 Distances inclination as duration increase

From scenario 1, the oil particle predicted reach Labuan shoreline within 16 hours traveling. Within this period, oil will normally break up and be dissipated or scattered into the marine environment over time.

This dissipation is a result of a number of chemical and physical processes that change the compounds that make up oil when it is spilled. The processes are collectively known as weathering. Oils weather in different ways. Some of the processes, like natural dispersion of the oil into the water, cause part of the oil to leave the sea surface, while others, like evaporation or the formation of water in oil emulsions, cause the oil that remains on the surface to become more constant.

In this case, if the spill are continuously happen and involve in a large number of volumes, the trajectory of the oil will predicted will affect some other places especially near to the west of Sabah shoreline. It will take some times, within three to five days to reach the shoreline. Based on figure classification of shoreline, it shows that some elements of coastal management will be affected.

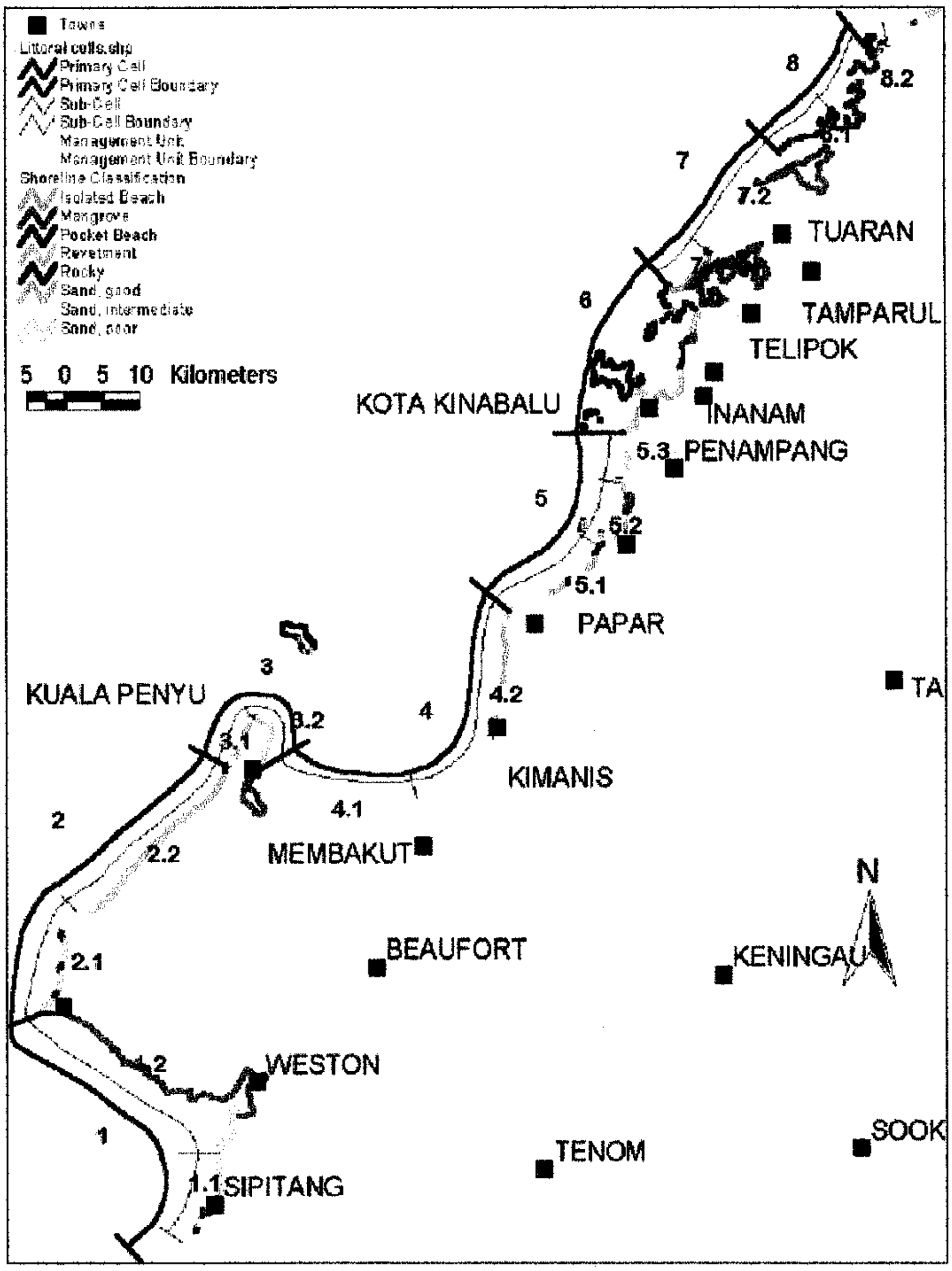

Figure 9 Sediment cells and sub-cells division West Coast of Sabah

DISTRICT	SHORELINE CLASSIFICATION (km)								
	Isolated Beach	**Mangrove**	**Pocket Beach**	**Revetment or Developed**	**Rocky**	**Sand, Good**	**Sand, Intermediate**	**Sand, Poor**	**Total coastline length (km)**
Tawau		231.0	2.4	15.8	1.3		6.5	2.0	259.0
Semporna		266.8	6.9	11.4	12.9		1.5		299.5
Kunak		41.6		2.2					43.8
Lahad Datu		163.2	2.8	11.8	0.9	3.8	64.1	5.1	251.7
Kinabatangan		152.4					51.2	13.8	217.4
Sandakan		282.7	6.9	16.5	5.9		4.0	27.5	343.5
Beluran		223.9						22.7	246.6
Pitas		140.7		3.1	0.9		5.6	20.7	171.0
Kudat		45.6	8.0	9.5	15.9	5.8	25.0	24.8	134.6
Kota Marudu		31.7			4.0		5.4		41.1
Kota Belud		14.5	11.3	0.6	32.1	14.7	19.2	1.4	93.8
Tuaran		107.9	5.5		6.4	1.7	12.2		133.7
Kota Kinabalu	3.1	7.0	10.4	21.3	47.9	5.5	2.4	7.2	104.8
Penampang	1.0	6.1		3.7	2.3		5.6	1.5	20.2
Papar	0.4	4.0		4.5	2.5	12.7	13.3	3.5	40.9
Beaufort		69.5					36.0		105.5
Kuala Penyu	2.4	15.9		0.4	18.9	28.5	9.1	15.5	90.7
Sipitang		1.9			2.1		1.1	15.5	20.6
Total	**6.9**	**1806.4**	**54.2**	**100.8**	**154.0**	**72.7**	**262.2**	**161.2**	**2618.4**

Table 6 Shoreline Classification

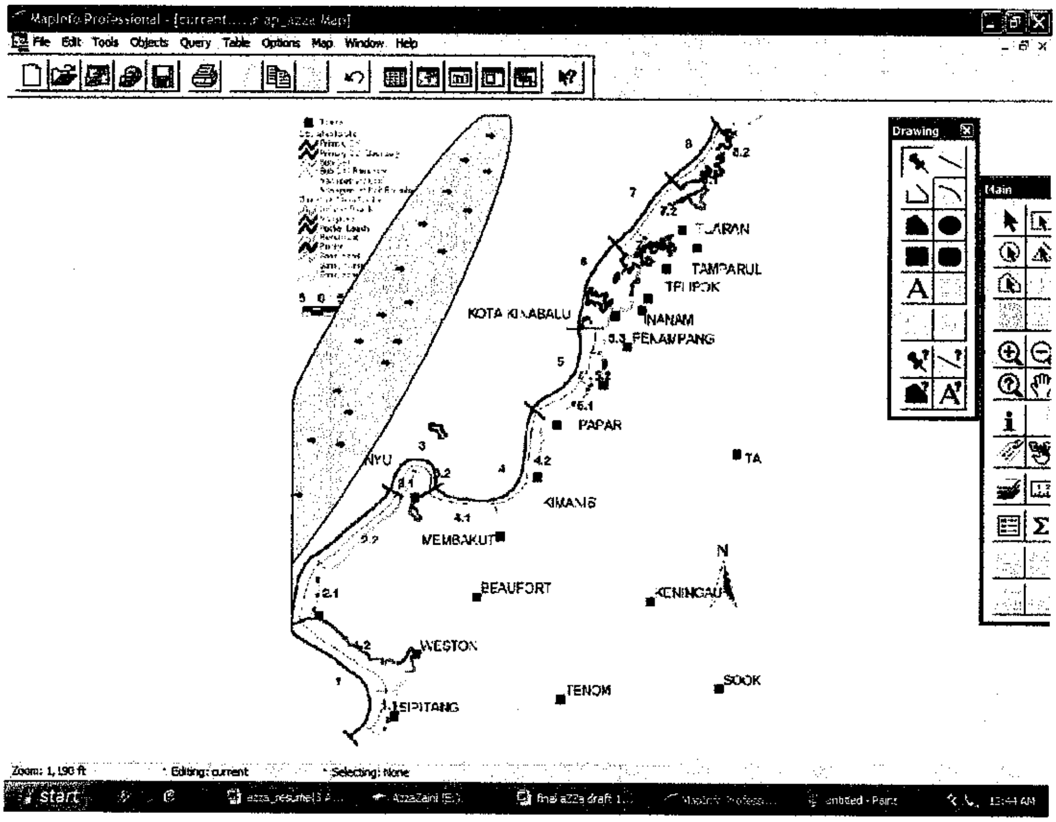

Figure 10 Layer: Current effect

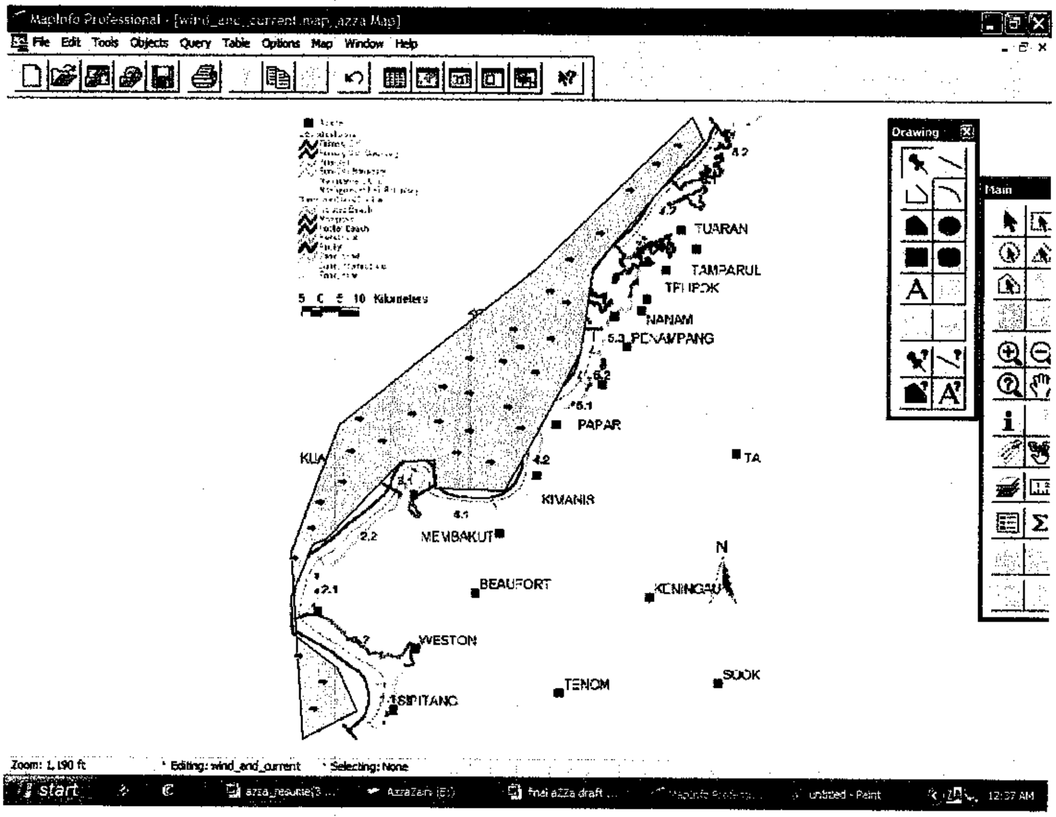

Figure 11 Layer: wind effect

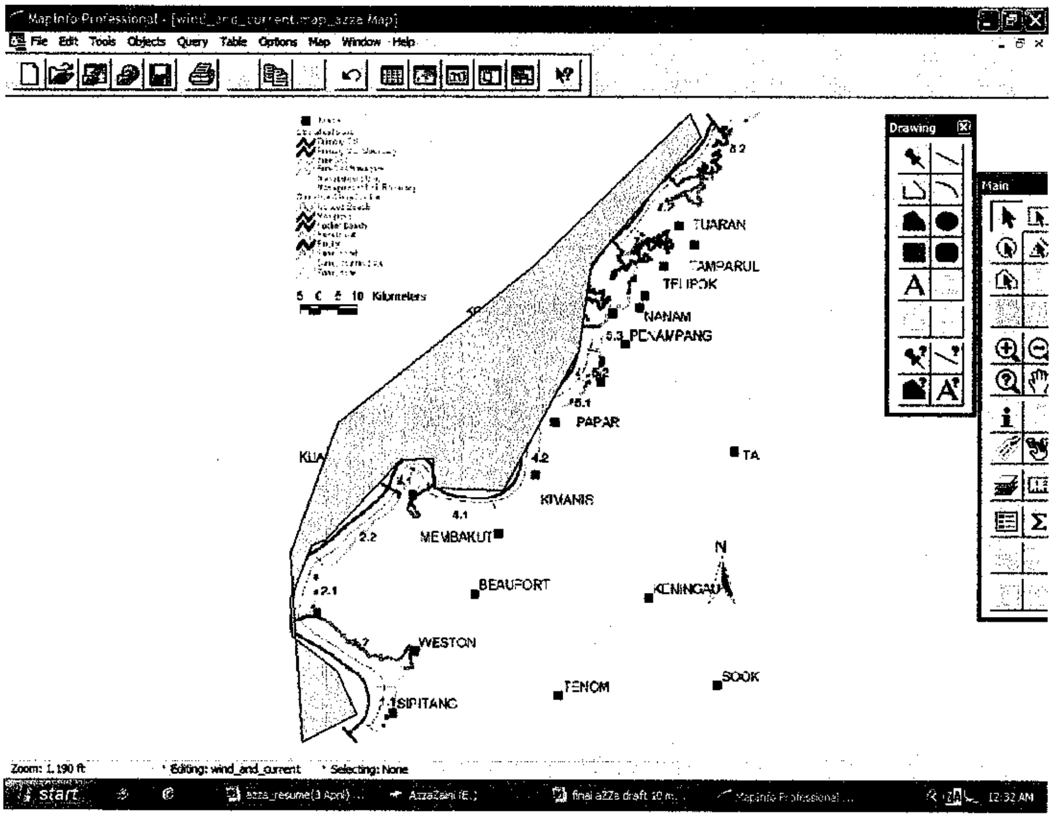

Figure 12 Layer: impact of oil to shoreline

5.4.1 Behaviors of oil at sea

The eight main processes that cause oil to weather are described below and summarized in the following diagram.

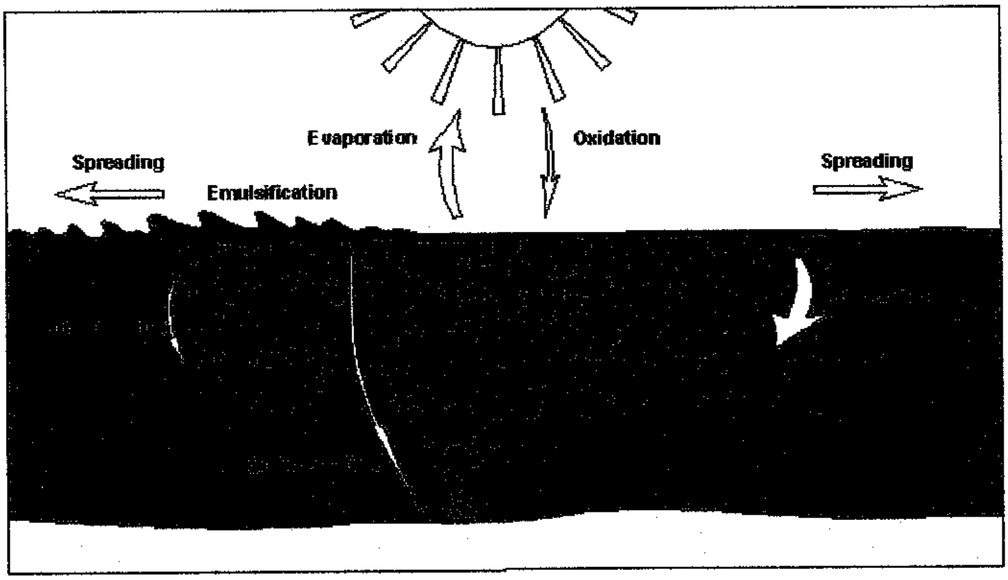

Figure 13 Fate of oil spilled at sea showing the weathering processes

Winds, wave action and water turbulence tend to cause oil to form narrow bands or 'windrows' parallel to the wind direction. At this stage the properties of the oil become less important in determining slick movement. The rate at which oil spreads or fragments are also affected by tidal streams and currents - the stronger the combined forces, the faster the process. There are many examples of spills spreading over several square kilometers in just a few hours and over several hundreds of square kilometers within a few days, thus seriously limiting the possibility of effective clean-up at sea. It should also be appreciated that, except in the case of small spills of low viscosity oils, spreading is not uniform and large variations of oil thickness from less than a micrometer to several millimeters can occur.

5.4.2 Impact of Oil on Coastal Activities

The effects of a particular oil spill depend upon many factors, not least the properties of the oil. Contamination of coastal amenity areas is a common feature of many spills leading to public concern and interference with recreational activities such as bathing, boating, angling and diving. Hotel and restaurant owners and others who gain their livelihood from the tourist trade can also be affected. The disturbance to coastal areas and to recreational pursuits from a single spill is comparatively short-lived and any effect on tourism is largely a question of restoring public confidence once clean-up is completed.

Industries that rely on a clean supply of seawater for their normal operations can be adversely affected by oil spills. If substantial quantities of floating or sub-surface oil are drawn through intakes, contamination of the condenser tubes may result, requiring a reduction in output or total shutdown whilst cleaning is carried out.

5.4.3 Biological Effects of Oil

Basically, the effects of oil on marine life are caused either by the physical nature of the oil (physical contamination and smothering) or by its chemical components (toxic effects and accumulation leading to tainting). Marine life may also be affected by clean-up operations or indirectly through physical damage to the habitats in which plants and animals live.

The main risk caused to living resources by the continual residues of spilled oils and water-in-oil emulsions ("mousse") is one of physical smothering. The animals and plants most at risk are those that could come into contact with a contaminated sea surface.

The most toxic components in oil tend to be those lost rapidly through evaporation when oil is spilt [6]. Sub-lethal effects that weaken the ability of individual marine organisms to reproduce, grow, feed or perform other functions can be caused by prolonged exposure to a concentration of oil or oil components far lower than will cause death.

Sedentary animals in shallow waters such as oysters, mussels and clams that routinely filter large volumes of seawater to extract food are especially likely to accumulate oil components. At the same time, these components may not cause any immediate harm; their presence may render such animals indigestible if they are consumed by man, due to the presence of an oily taste or smell. This is a temporary problem since the components causing the taint are lost when normal conditions are restored.

The ability of plants and animals to survive contamination by oil varies. The effects of an oil spill on a population or habitat must be viewed in relation to the stresses caused by other pollutants or by any exploitation of the resource. In view of the natural variability of animal and plant populations, it is usually extremely difficult to assess the risks of an oil spill and to determine when a habitat has recovered to its pre-spill state.

In recognition of this problem detailed pre-spill studies are sometimes undertaken to define the physical, chemical and biological characteristics of a habitat and the pattern of natural variability. A more productive approach is to identify which specific resources of value might be affected by an oil spill and to restrict the study to meeting defined and realistic aims, related to such resources.

5.4.4 Impact of Oil on Specific Marine Habitats

The following are summaries of the impact that oil spills can have on selected marine habitats. Within each habitat a wide range of environmental conditions exist and often there is no clear division between one habitat and another.

South China Sea is known to be suitable place for plankton to live. Plankton is a term applied to floating plants and animals carried passively by water currents in the upper layers of the sea. Their sensitivity to oil pollution has been demonstrated experimentally. In the open sea, the rapid dilution of naturally dispersed oil and its soluble components, as well as the high natural death and inconsistent, irregular distribution of plankton, make significant effects unlikely.

In coastal areas some marine mammals and reptiles, such as turtles, may be particularly at risk to adverse effects from oil contamination because of their need to surface to breathe and to leave the water to breed. Adult fish living in near shore waters and juveniles in shallow water nursery grounds may be at greater risk to exposure from dispersed or dissolved oil.

The risk of surface oil slicks affecting the sea bed in offshore waters is minimal. However, restrictions on the use of dispersants may be necessary near spawning grounds or in some sheltered, near shore waters where the dilution capacity is poor. The impact of oil on shorelines may be particularly great where large areas of rocks, sand and mud are uncovered at low tide. The amenity value of beaches and rocky shores may require the use of rapid and effective clean-up techniques, which may not be compatible with the survival of plants and animals.

Marsh vegetation shows greater sensitivity to fresh light crude or light refined products whilst weathered oils cause relatively little damage. Oiling of the lower portion of plants and their root systems can be lethal whereas even a severe coating on leaves may be of little consequence especially if it occurs outside the growing season. In tropical area like Kota Kinabalu, mangrove forests are widely distributed and replace salt marshes on sheltered coasts and in estuaries. Mangrove trees have complex breathing roots above the surface of the organically rich and oxygen-depleted muds in which they live. Oil may block the openings of the air breathing roots of mangroves or interfere with the trees' salt balance, causing leaves to drop and the trees to die. Protection of wetlands, by responding to an oil spill at sea, should be a high priority since physical removal of oil from a marsh or from within a mangrove forest is extremely difficult.

Living coral grows on the calcified remains of dead coral colonies which form overhangs, gaps and other irregularities inhabited by a rich variety of fish and other animals. If the living coral is destroyed the reef itself may be subject to wave erosion. The effects of oil on corals and their associated fauna are mainly determined by the quantity of toxic components, the duration of oil exposure as well as the degree of other stresses. The waters over most reefs are shallow and turbulent, and few clean-up techniques can be recommended.

Birds which gather together in large numbers on the sea or shorelines to breed, feed are particularly exposed to oil pollution. Although oil consumed by birds during cleaning may be poisonous, the most common cause of death is from drowning, starvation and loss of body heat following damage to the plumage by oil.

5.4.5 Impact of Oil on Fisheries and Mariculture

An oil spill can directly damage the boats and gear used for catching or cultivating marine species. Floating equipment and fixed traps extending above the sea surface are more likely to become contaminated by floating oil whereas submerged nets, pots, lines and bottom trawls are usually well protected, provided they are not lifted through an oily sea surface.

Cultivated stocks are more at risk from an oil spill: natural avoidance mechanisms may be prevented in the case of captive species, and the oiling of cultivation equipment may provide a source for prolonged input of oil components and contamination of the organisms. The use of dispersants very close to mariculture facilities is ill-advised since tainting by the chemical or by the dispersed oil droplets may result.

An oil spill can cause loss of market confidence since the public may be unwilling to purchase marine products from the area irrespective of whether the seafood is actually tainted. Bans on the fishing and harvesting of marine products may be imposed following a spill, both to maintain market confidence and to protect fishing gear and catches from contamination.

CHAPTER 6
DISCUSSION

6.1 Oil Trajectory Analysis

Basically there are two approach in order analyze the projection of oil particles whether by using Trajectory calculator and linear velocity calculation. It should be appreciated that the movement of an oil slick on the sea surface is due to winds and surface currents, and may be influenced by the combined weathering processes. The actual mechanisms governing spill movement are complex, but experience shows that oil drift can be predicted from a simple vector calculation of wind and surface current direction, based on about 3% of the wind speed and 100% of the current velocity. Reliable prediction of slick movement is clearly dependent upon the availability of good wind and current data. Accurate current data are sometimes difficult to obtain. For some areas it is presented on charts or tidal stream atlases but often only general information is available. In shallow waters near the coast or among islands, currents may be complex and are often poorly understood, rendering accurate prediction of slick movement particularly difficult.

6.2 Fate and behavior of oil in the marine environment

Qualitatively the impact of the leakage can be divided into several aspects such as biological impact, social impact, and environmental impact and sometime it could affect on political issues when it is entering the outer boundaries. Some of the biological and environmental issue are stated below are some of the study that carried out by organization and individual in order to understand the impact.

Complex processes of oil transformation in the marine environment start developing from the first seconds of oil's contact with seawater. The sequence, duration, and result of these transformations depend on the properties and composition of the oil itself, parameters of the actual oil spill, and environmental conditions. The main characteristics of oil transformations are their dynamism, especially at the first stages, and the close interaction of physical, chemical, and biological mechanisms of dispersion and degradation of oil components up to their complete disappearance as original substances.

6.2.1 Physical transport

Generally, the dispersal of oil particle on the sea surface occurs under the influence of gravitation forces. It is controlled by oil viscosity and the surface tension of water. According to Ramade, only ten minutes after a spill of 1 ton of oil, the oil can disperse over a radius of 50 m, forming a slick 10-mm thick. The slick gets thinner (less than 1 mm) as oil continues to spread, covering an area of up to 12 km^2 [Ramade, 1978]. During the first several days after the spill, a considerable part of oil transforms into the gaseous phase. Besides volatile components, the slick rapidly loses water-soluble hydrocarbons. The more viscous fractions, more slow down the slick spreading. Further changes occur under the combined impact of meteorological and hydrological factors and mainly depend on the vectors of wind, waves, and currents.

An oil slick usually drifts in the same direction as the wind. While the slick thins, especially after the critical thickness of about 0.1 mm, it disintegrates into separate fragments that spread over larger and more distant areas. Storms and active turbulence speed up the dispersion of the slick and its fragments. A considerable part of oil disperses in the water as fine droplets that can be transported over large distances away from the place of the spill.

6.2.2 Dissolution

Most oil components are water-soluble to a certain degree, especially low-molecular-weight aliphatic and aromatic hydrocarbons. Polar compounds formed as a result of oxidation of some oil fractions in the marine environment also dissolve in seawater. Compared with evaporation, dissolution takes more time. Hydrodynamic and physicochemical conditions in the surface waters strongly affect the rate of the process.

6.2.3 Emulsification

Oil emulsification in the marine environment depends, first of all, on oil composition and the turbulent regime of the water mass. The most stable emulsions such as water-in-oil contain from 30% to 80% water. They usually appear after strong storms in the zones of spills of heavy oils with an increased content of nonvolatile fractions (especially asphaltenes). They can exist in the marine environment for over 100 days in the form of peculiar "chocolate mousses". Stability of these emulsions usually increases with decreasing temperature. The reverse emulsions, such as oil-in-water (droplets of oil suspended in water), are much less stable because surface-tension forces quickly decrease the dispersion of oil. This process can be slowed with the help of emulsifiers - surface-active substances with strong hydrophilic properties used to eliminate oil spills. Emulsifiers help to stabilize oil emulsions and promote dispersing oil to form microscopic (invisible) droplets. This accelerates the decomposition of oil products in the water column.

6.2.4 Oxidation and destruction

Chemical transformations of oil on the water surface and in the water column start to expose within a day after the oil enter the marine environment. They mainly have an oxidative nature and often involve photochemical reactions under the influence of ultraviolet waves of the solar spectrum. These processes are catalyzed by some trace elements (e.g., vanadium) and inhibited (slowed) by compounds of sulfur. The final products of oxidation (hydroperoxides, phenols, carboxylic acids, ketones, aldehydes, and others) usually have increased water solubility. An experimental research showed that they have increased toxicity as well the reactions of photooxidation, photolysis in particular, initiate the polymerization and decomposition of the most complex molecules in oil composition. This increases the oil's viscosity and promotes the formation of solid oil aggregates [4].

6.2.5 Sedimentation

Some of the oil (up to 10-30%) is adsorbed on the suspended material and deposited to the bottom. This mainly happens in the narrow coastal zone and shallow waters where particulates are abundant and water is subjected to intense mixing. In deeper areas remote from the shore, sedimentation of oil (except for the heavy fractions) is an extremely slow process. Simultaneously, the process of biosedimentation happens. Plankton filtrators and other organisms absorb the emulsified oil. The suspended forms of oil and its components undergo intense chemical and biological (microbial in particular) decomposition in the water column. However, this situation radically changes when the suspended oil reaches the sea bottom. Numerous experimental and field studies show that the decomposition rate of the oil buried on the bottom immediately drops. The oxidation processes slow down, especially under anaerobic conditions in the bottom environment. The heavy oil fractions accumulated inside the sediments can be preserved for many months and even years.

6.2.6 Microbial degradation

The fate of most petroleum substances in the marine environment is ultimately defined by their transformation and degradation due to microbial activity. About a hundred known species of bacteria and fungi are able to use oil components to sustain their growth and metabolism. In pristine areas, their proportions usually do not exceed 0.1-1.0% of the total abundance of heterotrophic bacterial communities. In areas polluted by oil, however, this portion increases to 1-10%. Biochemical processes of oil degradation with microorganism participation include several types of enzyme reactions based on oxygenases, dehydrogenases, and hydrolases. These cause aromatic and aliphatic hydrooxidation, oxidative deamination, hydrolysis, and other biochemical transformations of the original oil substances and the intermediate products of their degradation.

The degree and rates of hydrocarbon biodegradation depend, first of all, upon the structure of their molecules. The paraffin compounds (alkanes) biodegrade faster than aromatic and naphthenic substances. With increasing complexity of molecular structure (increasing the number of carbon atoms and degree of chain branching) as well as with increasing molecular weight, the rate of microbial decomposition usually decreases. Besides, this rate depends on the physical state of the oil, including the degree of its dispersion. The most important environmental factors that influence hydrocarbon biodegradation include temperature, concentration of nutrients and oxygen, and, of course, species composition and abundance of oil-degrading microorganisms. These complex and interconnected factors influencing biodegradation and the variability of oil composition make interpreting and comparing available data about the rates and scale of oil biodegradation in the marine environment extremely difficult.

6.2.7 Aggregation

Oil aggregates in the form of petroleum lumps, tar balls, or pelagic tar can be presently found both in the open and coastal waters as well as on the beaches. They derive from crude oil after the evaporation and dissolution of its relatively light fractions, emulsification of oil residuals, and chemical and microbial transformation. The chemical composition of oil aggregates is rather changeable. However, most often, its base includes asphaltenes (up to 50%) and high-molecular-weight compounds of the heavy fractions of the oil.

Oil aggregates look like light gray, brown, dark brown, or black sticky lumps. They have an uneven shape and vary from 1 mm to 10 cm in size (sometimes reaching up to 50 cm). Their surface serves as a substrate for developing bacteria, unicellular algae, and other microorganisms. Besides, many invertebrates (e.g., gastropods, polychaetes, and crustaceans) resistant to oil's impacts often use them as a shelter. Oil aggregates can exist from a month to a year in the enclosed seas and up to several years in the open ocean. They complete their cycle by slowly degrading in the water column, on the shore (if they are washed there by currents), or on the sea bottom (if they lose their floating ability).

6.3 Responding to oil spills

If oil is spilled far from land, or if it is a light oil which is likely to evaporate quickly, almost all will be dealt with by nature, and the most appropriate response might be to take no action other than monitoring the spill and reporting to the relevant authorities (while making sure that equipment and resources can immediately be made available, if required).

A number of "clean-up" techniques can be employed. These include:

- Spraying the oil with low toxicity dispersant chemicals from low-flying aircraft. The chemicals help break up the oil and disperse it into the sea where it can be broken down by naturally-occurring micro-organisms.

- Using "skimmer-vessels" - specially adapted boats which skim the surface of the sea, removing floating oil.
- Placing floating booms across harbours and inlets to restrict oil movement physically.

In addition, a task force can work on shores in threatened areas to rescue and clean as much wildlife as possible and to clean beaches. These methods may be hampered by bad weather or by the fact that oil spreads quickly and also absorbs large amounts of water to form an emulsion or mousse.

If oil is washed ashore on a hard sandy beach it can be quickly and effectively cleared by manpower helped by mechanical equipment like bulldozers and trucks.

Rocky shorelines are harder to clear and it may only be possible to remove oil which has accumulated on the surface. Muddy shores and salt marshes are very difficult to clean and are often badly damaged by attempting to clear oil manually or with mechanical equipment. They are often best left to recover naturally.

Several schemes have been set up to pay compensation in the event of a serious oil spill. Two of these are international conventions developed by the International Maritime Organization. These arrangements only apply in countries which have formally agreed to accept them. There are also two voluntary schemes set up by the tanker and oil industries, and these arrangements can apply worldwide. These arrangements have been more than adequate to compensate the victims of tanker spills, with only a very few exceptions.

CHAPTER 7
CONCLUSION

GIS-based risk management system uses the latest spatial information technology to store data required for oil spill risk assess, response, planning, training and risk management. The integration of risk assessment with GIS techniques offers an effective tool for analysis of the risk management. Analysis of the oil spill with the Mapinfo software will help to predict the location and area affected by the incident. With the Oil Trajectory Calculator modeling, the Oil Spill Response Management System (OSRMS) could help the user to predict the movement of oil and assess the risk of the spills more efficient and well managed. As a result, this will improve the local management strategies in order to keep the shoreline well protected.

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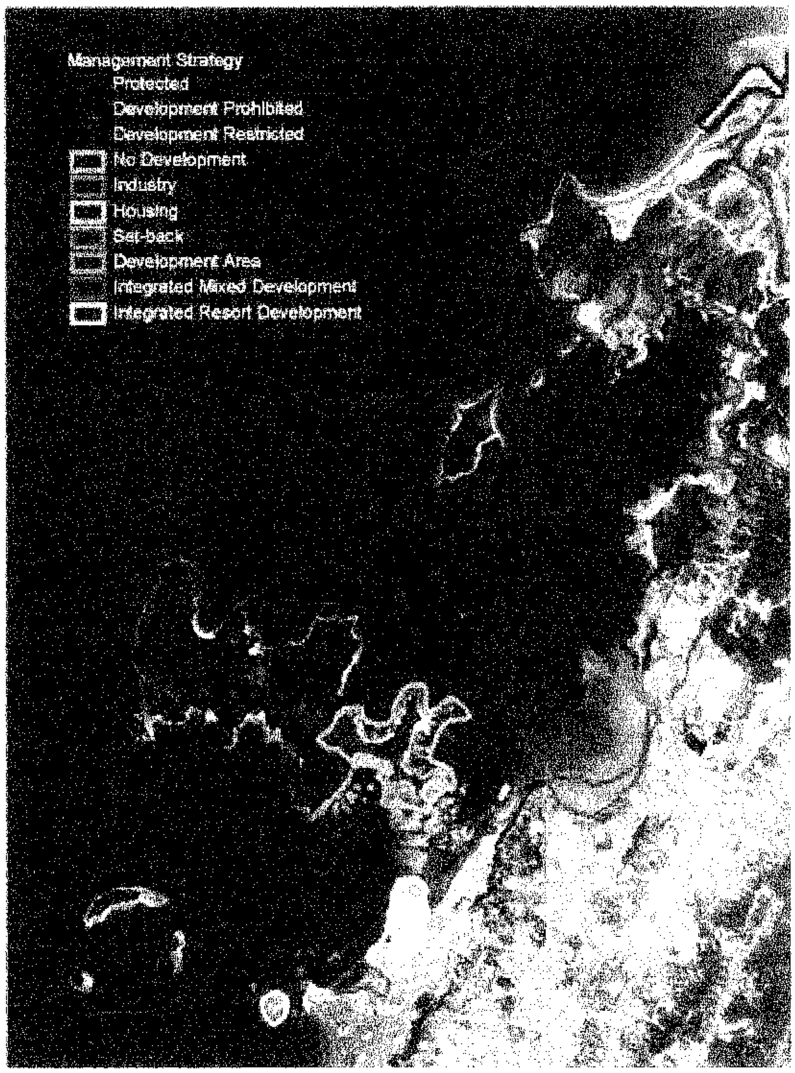
APPENDIX A

SHORELINE MANAGEMENT PLAN, KOTA KINABALU

Figure: Shoreline Management Plan, Kota Kinabalu.



APPENDIX B

INFORMATION ON WETLAND IN SABAH

Source: WWF Sabah Conservation Strategy Volume 2

Relevant information obtained from the above report regarding wetland area is shown in Tables below.

Table: Mangrove Forest Areas - Class III

Name	Present Size (ha)
Abai	1396
Bengkoka Peninsula	13283
Elopura	24674
Gum Gum	3086
Kuala Bonggaya & Kuala Labuk	56912
Kuala Segama & Kuala Maruap	23993
Kuala Tingkaya	4745
Kudat & Marudu	13636
Lahad Datu	11066
Menumbok	5710
Pulau Banggi	11504
Semporna	23400
Sibyte	2364
Sulaman Lake	2635
Sg. Sugut, Paitan, Pulau Jambongan	38564
Tawau	39018
Trusan Kinabatangan	40471
TOTAL	**316457**
	4.3% of the total area

Source: WWF Sabah Conservation Strategy Volume 2 (pg. 127)

Table : Virgin Jungle Reserves - Class VI (Status: All Totally Protected Areas) Mangroves only

Name	Present Size (ha)
Batumapun	164
Sepilok	1235
TOTAL	1399

Source: WWF Sabah Conservation Strategy Volume 2 (pg. 128)

APPENDIX C

MALAYSIAN INTERIM WATER AND AIR QUALITY STANDARD

Table: Interim National Water Quality Standards for Malaysia

Parameter	Unit	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Temperature	o C	-	normal	-	normal	-	-
pH		6.5 - 8.5	6 - 9	6 - 9	5 - 9	5 - 9	-
Conductivity	6_F_	1000	1000	-	-	6000	-
Colour	Pt -CO	15	150	150	-	-	-
DO	mg/L	7	5 - 7	5 - 7	3 - 5	< 3	< 1
BOD	mg/L	1	3	3	6	12	> 2
COD	mg/L	10	25	25	50	100	> 100
Oil & Grease	mg/L	natural	40; nil	nil	-	-	-
Dissolved solids	mg/L	500	1000	-	-	4000	-
Suspended solids	mg/L	25	50	50	150	300	> 300
Turbidity	NTU	5	50	50	-	-	-
Ammonia – N	mg/L	0.1	0.3	0.3	0.9	2.7	> 2.7
Floatables		nil	nil	nil	-	-	-
Odour			nil	nil	nil	-	-
Salinity	10-3	0.5	1	-	-	2	-
Taste		nil	nil	nil	-	-	-
E. coli	MPN/100mL	10	100	400	5000	5000	-
Total coliform	MPN/100mL	100	5000	5000	50000	50000	> 50000
Hardness	mg/L	natural	250	250	-	-	-
K	mg/l	natural	-	-	-	-	-
F	mg/l	natural	1.5	1.5	10	1	> 1
NO3	mg/l	natural	7	7	-	5	> 5
P	mg/L	natural	0.2	0.2	0.1	-	-
S	mg/L	natural	0.05	0.05	0.001	-	-
Cd	mg/L	natural	0.01	0.01	0.01	0.01	> 0.01
Cu	mg/L	natural	1	1	-	0.2	> 0.2
Fe	mg/L	natural	0.3	0.3	1	1 - 5	> 5
Pb	mg/L	natural	0.05	0.05	0.02	5	> 5
Mn	mg/L	natural	0.1	0.1	0.1	0.2	> 0.2

Table: DOE Interim Sea Water Quality Standards

Parameter	Standard
E. coli (MPN/100ml)	100
Oil & Grease (mg/l)	0
Suspended Solids (mg/l)	50
Cadmium (mg/l)	0.01
Chromium (mg/l)	0.5
Lead (mg/l)	0.1
Nickel (mg/l)	0.01
Copper (mg/l)	0.1