GIS FOR ENVIRONMENTAL DAMAGE OF OIL PIPELINE LEAKAGE

By

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Final report submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

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CERTIFICATION OF APPROVAL

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A project interim submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
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Approved by,

(Dr Abdul Nasir Bin Matori)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

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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.

HELMI BIN YUSUF

ABSTRACT

The paper describes the use of spatial analysis on Geographical Information System in analyzing the environmental damage cause by pipeline leakage. For the first part of the project, the author describe about his background, objective and scope of the study. The second chapter of the paper particularly emphasis on the research done on the literature review regarding the environmental damage of oil. It either because of the pipeline leakage or oil spill from tanker. Then, the paper emphasis on the pipeline and oil properties. The paper also discusses on the role of GIS as an effective tool to asses the damage of the pipeline leakage. The method use by the author to develop database is discuss in chapter three. In chapter four, the author discusses and demonstrates the developed database. The result and discussion of spatial analysis is discussed in depth in chapter five and followed by conclusion in chapter six.

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious, the most Merciful, raise to him the Almighty, I had manage to complete this final project.

I want to thank to Dr Abd Nasir Matori, whose continuously give support, supervision and guiding me through the whole year. My sincere thanks to Petronas for the data that had been provided to me. Without the data, this project will unable to completed.

I have furthermore to thank the Malaysia Meteorological Data to do necessary research work and to use the department data. Without the data, would not be able to do the necessary analysis in my project.

I also want to thank my family and friends whose support me with my project.

Thank you.

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CHAPTER 1
INTRODUCTION

Concern is often raised about the possible oil pipeline leakage in the ocean. This is due to the impact of the leakage to the environment is very serious. The impact will influence the marine ecosystem to the particular area. Human also affected through the dependent on the marine life as food and as the economic activity which depend on the marine life. Nowadays, the environmental protection already becomes a big issue through the globe. Every year, there are a lot of activist express their protest against the party that contribute to the sea pollution.

1.1 Background Study.

This study aim is to develop a database by using Geographical Information System. The database contains related information regarding the oil pipeline, geospatial data and also attributes data. The geospatial data and attribute are related to the environment element. The important elements are flora and fauna of the surrounding are of the pipeline. These features are very effective tool to evaluate the impact of the pipeline leakage.

1.2 Problem Statement.

The increasing of oil price and demand has lead to the increasing oil production. The oil companies are competing for these purposes. They have expanded their exploration activities with hope to fine more oil reservoir to accommodate the demand. More reservoir mean more pipeline will be install to transport the oil to onshore facilities.

This competitive pressure and regulatory constrain are placing increasing demand on pipeline operator to operate in an efficient and responsible manner. Health, safety, and environmental protection are an important issue in petroleum production. The incident of pipeline leakage can cause a major damage to the environment.

1.3 **Objective of Study.**

- To develop the GIS database by integrating the oil pipeline map with the related spatial data and attribute data.
- To develop the relevant geospatial analysis of the oil leakage scenario.

1.4 Scope of Study.

The study on environmental impact of oil pipeline leakage through GIS application is to be completed within the time frame given which is approximately 2 semesters. The scope for the first semester is to familiarize with the GIS software and data collection for the database.

The location for this study is the offshore and along the shore of East Malaysia. To accomplish the study, research, allocating the resource, work planning is to be done within this time frame. The study more toward the marine impact and the mangrove forest along the shoreline. This study also involving the GIS software application to perform certain spatial analysis such as buffering and overlying so that the damage of marine life and environment could be assess.

CHAPTER 2
LITERITURE REVIEW

2.1 Environmental Impact Assessment.

According to Alan Giplin (1995), environmental impact assessment is a planning that is main purpose is to give it due place in the decision making process. It is being done by clearly evaluating the environmental consequences of a propose development before action is taken. The concept has ramification in the long period of time for all development activity because sustainable development depend on the prospecting the natural resource which is foundation for further development.

The environmental impact assessment aim is to predict the environmental destruction at an early stage in the project planning design. In this study, the assessment also being used as long as there is an oil production activity. This is to provide the immediate respond if the pipeline is burst or leaking.

The oil and gas industries are well known for its stringent self regulatory approach in pollution prevention. Despite this effort, marine pollution from sea based activities continues to occur and to threaten the marine environment. In Malaysia, the sources of oil pollution are from vessel illegal discharging, vessel collision, oil terminal and depot, and offshore exploration and production. The chart below shows the percentage of oil pollutant source based on reported cases from 1976 – 2000.

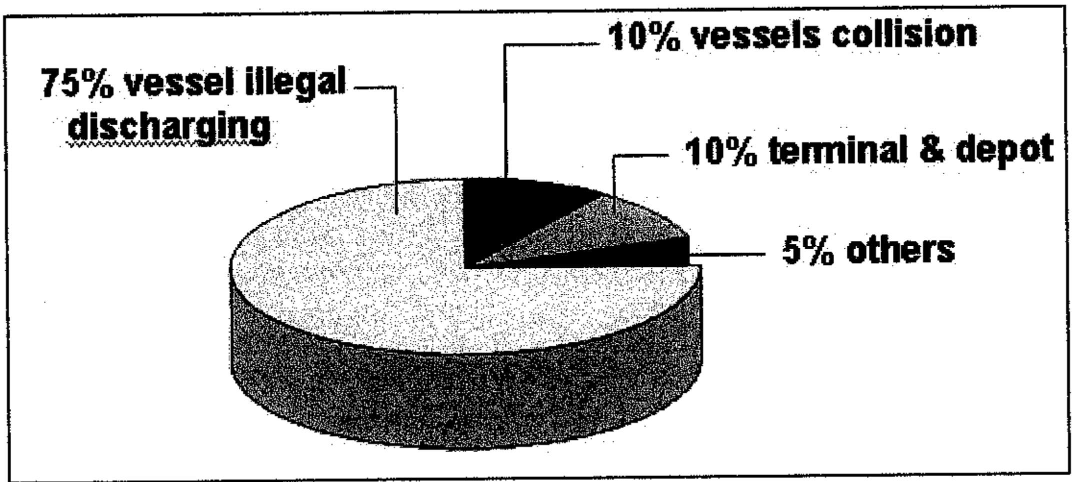

Figure 1: The Source of Pollution

There is a lot of oil as pollutant cases recorded pollute the environment. For example, on 15 February 1996 the Sea Empress, bringing crude oil to Milford Haven in south-west Wales, ran aground and over the following week release 72,000 tonnes of crude oils and 480 tonnes of fuel oil into the sea.

Despite a rapid and effective clean-up response at sea, oil came ashore along 200km of coastline- much of it in a National Park – and area for of international importance for its wildlife and natural beauty. A ban was imposing on commercial and recreational fishing in the region and there was concern that tourism, important to the local economy, would be badly affected by the heavily oiled beaches. Several thousand oil birds washed ashore, leading to a major cleaning and rehabilitation operation.

It is clearly impossible to cover every aspect of the ecology of the region, but all main type of onshore and marine environments were included in the environmental impact assessment program by Sea Empress Environmental Evaluation Committee (SEEEC). They were focusing on the key species that were:

- Heavily impacted by the oil,
- Indicate the health of the environment,
- Of conservation importance to the area,
- Important in the marine food chain,
- Of economic value.

The fishing industry is centre around the Milford Haven waterway. The region as abundant shellfish, crab, lobster, sea bass and other fish, and the local salmon and sea-trout rivers attract many visiting anglers. These fisheries provide an estimated 1000 land and sea based job. Agriculture in the regions includes early potatoes and vegetables, dairy and livestock farming.

Crude oil is a mixture of a very large number of different components. Test at the spill showed that about 40% of the oil, including many of the component that are toxic to marine life. It evaporated rapidly after release. For much of this period the wind are offshore. oil is natural product ad eventually most of it will have been broken down by micro organism in the water. By the end of March concentration of oil were low and near to background level over the effected area.

South-west Wales supports about half a million breeding seabirds, including internationally important populations of gannets, Manx shearwaters, razorbills, storm petrels and puffins. Around 7,000 oiled birds were washed ashore following the spill. But, may be it is likely that the total number of birds killed was several times higher than this. Examination of seabird corpses suggested that most died directly from oil contamination rather than, for example, food chain effects.

Over 90% of the oiled birds were of three species – common scoter, guillemot and razorbill. Diver species wintering in the area also proved vulnerable, with a high proportion oiled and washed ashore. In contrast, and despite their abundance, very few dead gulls were found on beaches. Counts of the breeding populations confirmed the impact on guillemots and razorbills. There were 13% fewer guillemots and 7% fewer razorbills counted at breeding colonies in the area in 1996 compared with 1995, while numbers for both species increased at nearby colonies. By the 1997 breeding season, numbers had recovered significantly.

Some species, particularly puffins, Manx shearwaters and storm petrels, had not returned to the area to breed and so avoided significant impact. Gannets were not affected as the oil did not reach the important nesting colony on Grassholm Island, the third largest in the world. The assessment of the effects on several other species, including the shag, remain equivocal as in some cases decreases in counts in 1996 were not restricted to the affected area.

In the weeks following the spill large numbers of dead or moribund animals were washed ashore, mostly bivalve mollusks, such as cockles, razor shells and sediment-dwelling animals of the lower shore and below the shoreline. This phenomenon can happen naturally with some species, but the timing, number of individuals, range of species and in some cases increased levels of tissue hydrocarbons suggested that most of the stranding were related to exposure to the oil.

Studies of the seabed showed little impact resulting from the spill except for the absence of amphipods (small crustaceans which are important in the food chain) in some areas near to the site of the spill. The death of amphipods and the stranding of molluscs have both been recorded following other major oil spills. The use of dispersants, in distributing oil droplets deep into the water column, may have increased the exposure to oil of those species living in sediments and contributed to the stranding and the decrease in amphipod populations in some areas.

2.2 Oil Pipeline.

Pipeline is design for full load operation. Operation parameters will range from maximum allowable operating pressure in exceptional circumstances to a degassed or depressurized state corresponding to a no flow situation. Normal pipeline operation may involve day to day transient such as pump start or stop operation, the operation of control valving and changes in delivery rates.

There are 2 type of pipeline leakage. The slow leakage can occur over a period of time consistent with the corrosion rates at weld point and fitting such as valves and strainers.

The example of slow leakage is seepage. The seepage rate would be expected to grow from pinhole size over a period of time without significant manifestation in pipe flow condition. The fault line may eventually yield under plastic strain and create a sudden rupture. Acoustic noise also accompanies the seepage.

The traditional leak is characterized by sudden changes in pipeline flowing condition at the leak site. The detection of the shock wave generate in the fluid medium at the moment of the rupture and then propagate as short lived transient at acoustic velocity can indicate that a leak has occur. The size of the pressure wave depends on the magnitude of the leak. The negative pressure wave traveling away from the leak site is reflected at each end of the pipe. This study will not involve in establish detecting method.

2.3 Oil Properties.

The oil pipeline leakage also can have serious economic impact on coastal activities and on those who exploit the resource of the sea. In most cases such damage is temporary and is cause primarily by the physical properties of oil creating nuisance and hazardous condition.

The important factor that determine the seriousness of the impact are oil type, oil loading (the thickness of deposits on the shore); local geography, climate and season; the biological communities and type of clean-up response. Different crude oil and oil product vary widely in their physical and chemical properties. Some are black, heavy and thick, while others are brown or nearly clear with low viscosity and low specific gravity.

Severe toxic effects are generally associates with hydrocarbon with low boiling point because these hydrocarbons are likely to penetrates and disrupt cell membrane. Spill of viscous heavy oil such as some crude and heavy fuel oil, may blanket areas of shore and kill organism primarily through smothering rather than through acute toxic effects.

Most of oil have the specific gravity less than 1, the sea water have the specific gravity about 1.025. Therefore the oil will float on top of the water and it is acting like a blanket to the water. In coastal areas, some marine mammal and reptiles such as turtle may be particularly vulnerable to the adverse effect because their need to surface to breath.

2.4 Environmental Application of GIS.

GIS give a wide framework where different discipline and topic can be accommodating into one database. The specific application play an important role in adapting different type of GIS tool and in many instance provide the basis for unification of these system. GIS can act like central information hub.

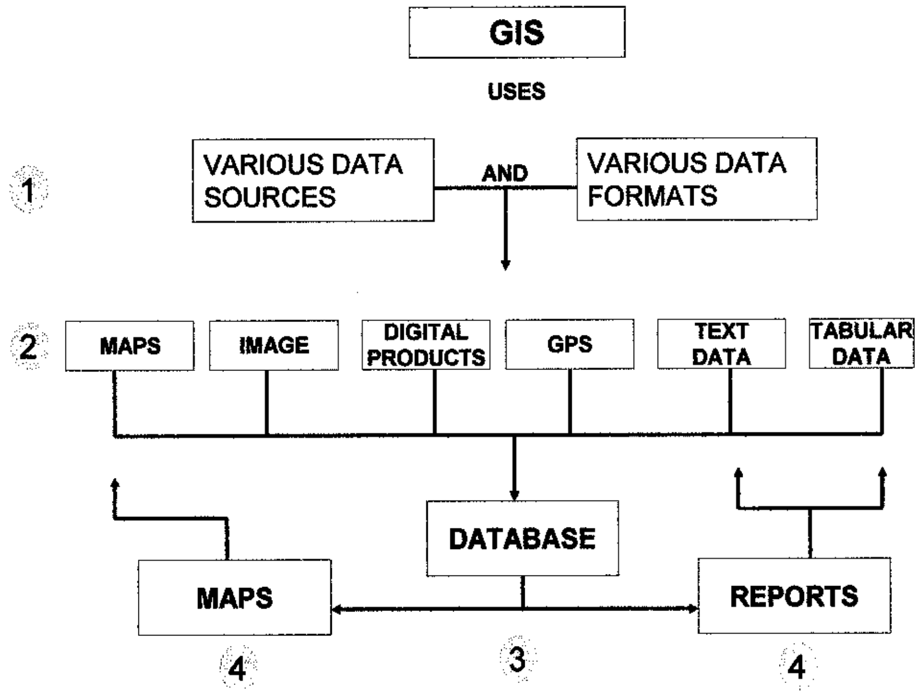

Figure 2: GIS acted like central information hub.

GIS can be broken down to 5 major activities. In its simples function, GIS can present data in a map form to communicate information.
Second, GIS can organize geographic data in the map, chart or table form to visualize spatial pattern in order o stimulate visual thinking. Third, GIS can query geographic point of interest and associates attributes to answer the question, "what and where?" fourth, it can provide new information by building geographic theme from older layers. Finally, GIS can also track pattern in space and time to aid in the function of analysis, decision making and workflow.

Nowadays GIS has become a very effective tool in environmental impact assessment. For example, the Nigerian government is naturally concern about the environmental hazards of oil production- drained wetlands; pollute rivers and streams, vanishing fish and wildlife. Consequently, oil companies working in the region must meet the strict environmental guidelines, and work with the government when exploring for oil reserves, building roads, dredging canal, or placing facilities near human or wildlife habitats.

Then, the Chevron's scientist imported satellite imagery and aerial survey data into their ArcView GIS system to create a base map of the region. They verified and corrected the position of fixed features like oil wells and roads with global positioning system (GPS) receivers. Other data, such as the location of the wetlands, endangered species, and human populations, was then added to the digital maps. Employees and manager are linked to the system, using it for range of application, from oil exploration project to planning oil spill response system.

The GIS always used if oil spilled. Spill data, maintain by the Nigerian government and oil companies operating in the companies, is brought into the ArcView GIS system and coded by factor like spill amount, time of day, and person or crew involved. This help Chevron's engineers search for the common theme – like a single crew involved in many incidents. When spill happen, the GIS can be used to identify priority shoreline and habitat that should be protected.

CHAPTER 3
METHODOLOGY

3.1 Procedure.

There are some procedure are develop in order to carry out this project. This is to ensure that the project flow is smooth and accomplish in the given period.

3.1.1 Research.

The research involve in this study scope are the research on procedure for the risk assessment, the properties and oil behaviors, the environmental impact of oil spill including on coastal activities, biologically, specific marine habitats, fisheries and mariculture.

3.1.2 Data Gathering.

The author must gather all the geospatial data and attribute data to develop the database. This information is retrieve from the related party. The data include the map of pipeline, fishing ground, crocodile, wildlife, turtle, aquaculture, shrimp, prawn, tourism beach, coral reef, surface reef, shore bird, mangrove forest, crab, and dolphin.

3.1.3 Developing GIS Database.

All the data gathered will be arrange properly and the author will transform the data into the layer of GIS software. The data will be arranged layer by layer for easy access and make analysis. The raw data can be in AutoCAD format or raster image. Data in format of AutoCAD is more easy to use. The Map info can convert the AutoCAD format to its own format.

3.2 Tool Required.

3.2.1 Map Info Software.

This is the GIS software and it used to present the geospatial data and attribute data such as the map.

3.2.2 AutoCAD 2006.

The purpose of this software is to be used as drawing tool. This software is very user friendly and capable of drawing in detail measurement.

3.2.3 Oil Water Trajectory Calculator.

This software used to analyze the physical properties of the oil under the effect of the wave and wind. Intuitive input of wind and current data, location information and times. Results update as user input data, allowing user to visualize effects of varying wind or currents. Imperial and metric data can be used for the input and results.

CHAPTER 4

MAP INFO DATABASED

The author has developed the map of pipeline, fishing ground, crocodile, wildlife, turtle, aquaculture, shrimp, prawn, tourism beach, coral reef, surface reef, shore bird, mangrove forest, crab, and dolphin.

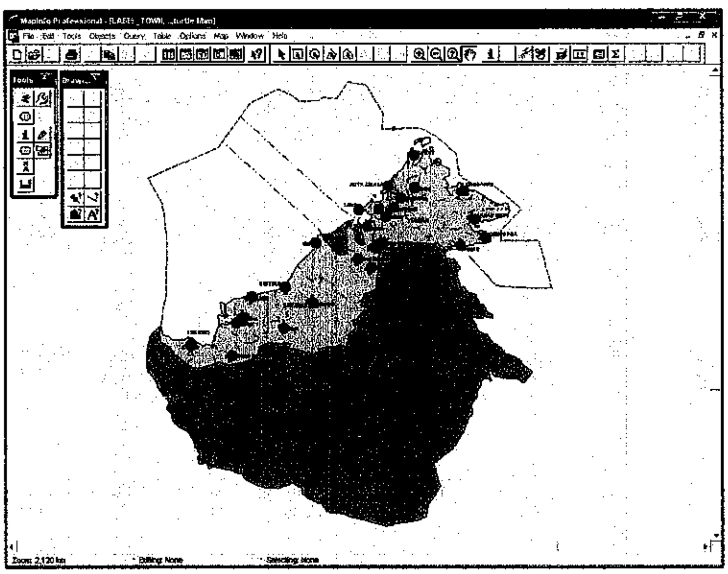

Figure 3: Map of Sabah & Sarawak.

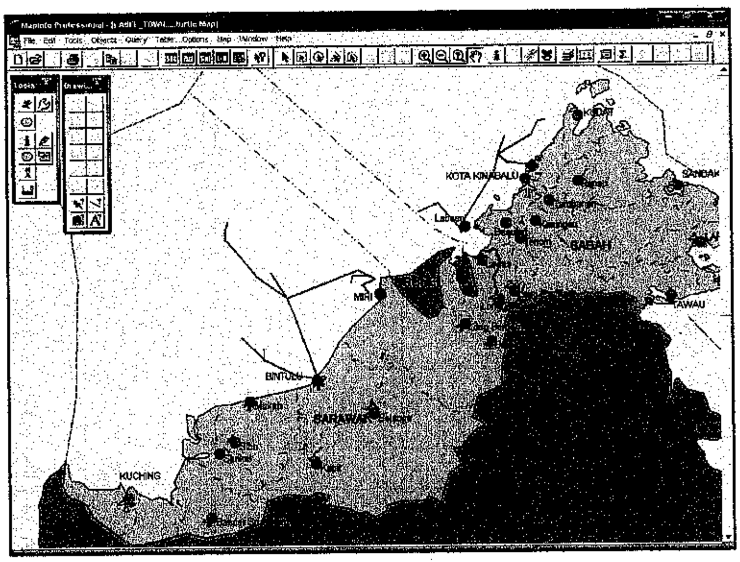

Figure 4: Pipeline offshore Sabah & Sarawak

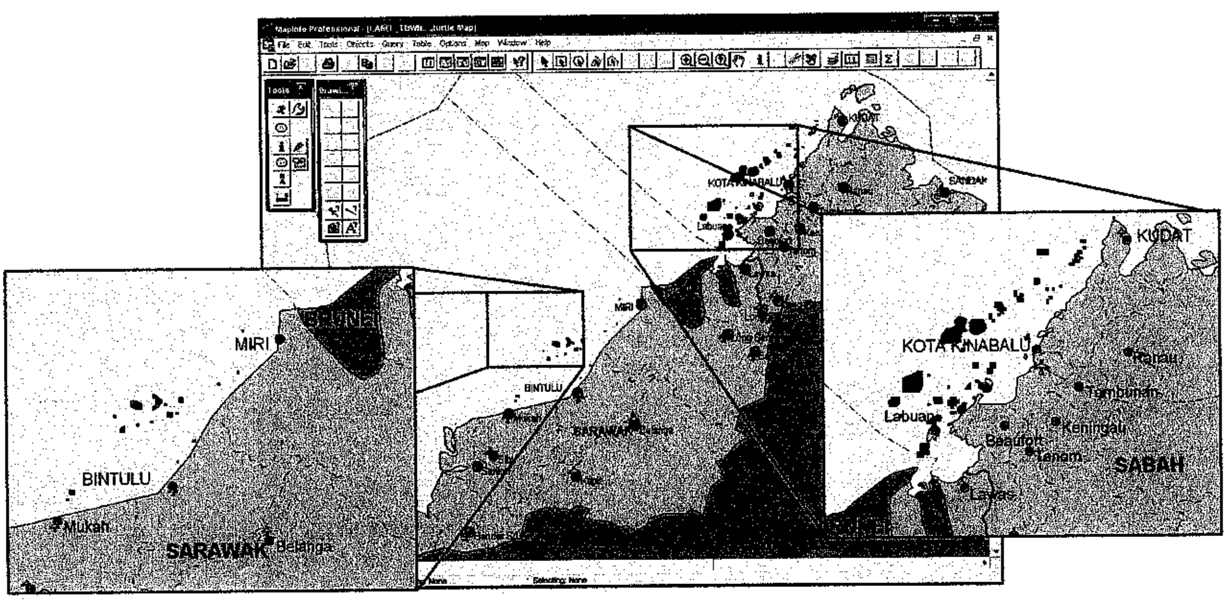

Figure 5: Map of coral reef.

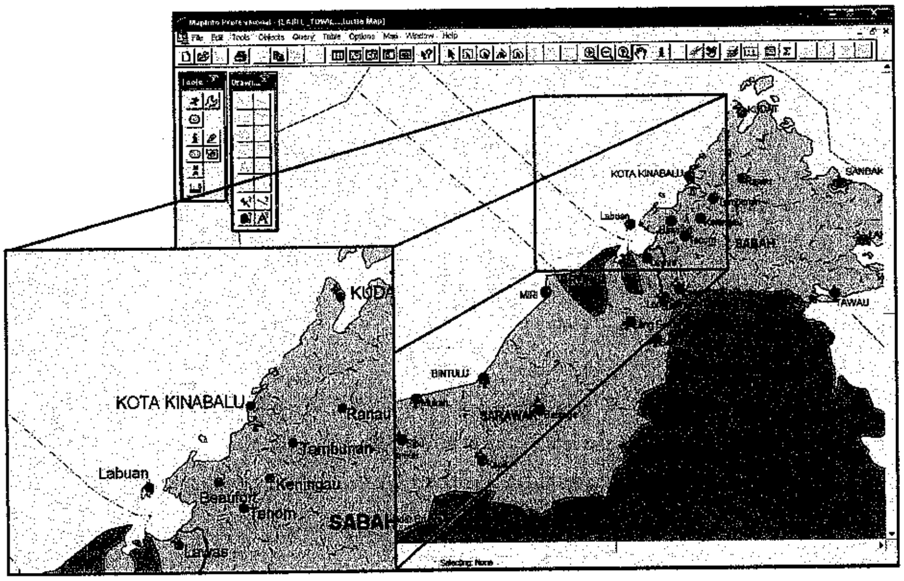

Figure 6: Map of surface reef.

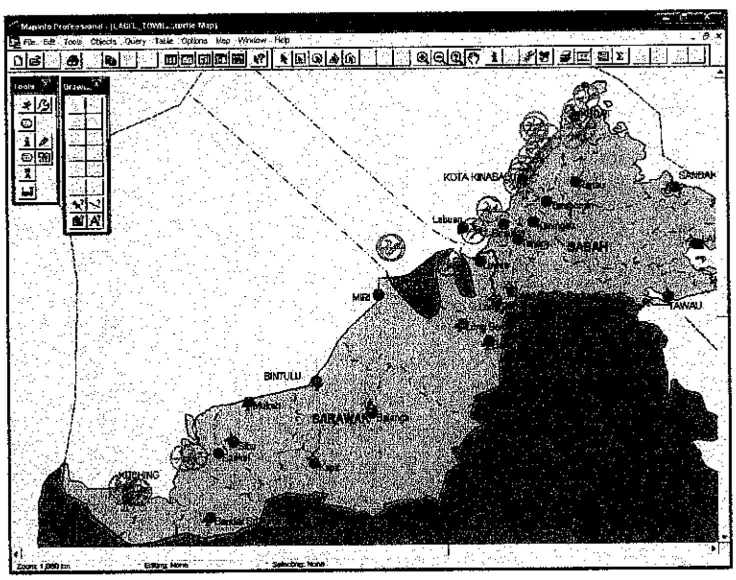

Figure 7: Map of aquaculture.

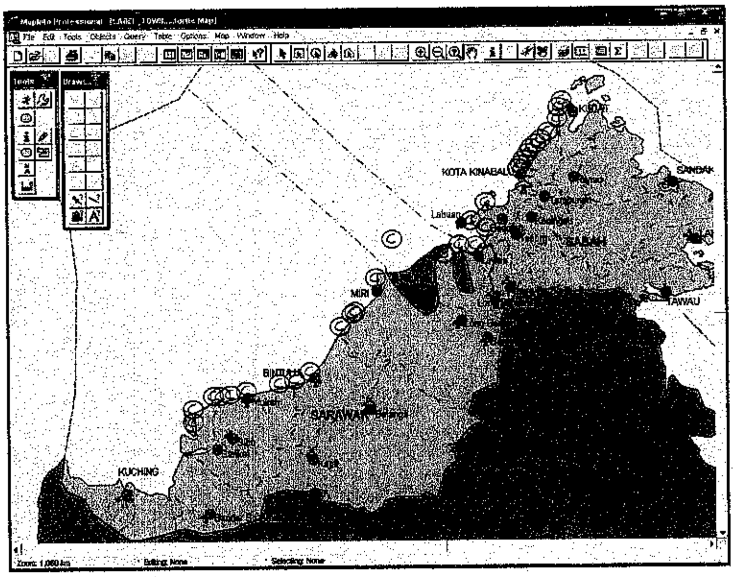

Fig. 8. Map of Crab.

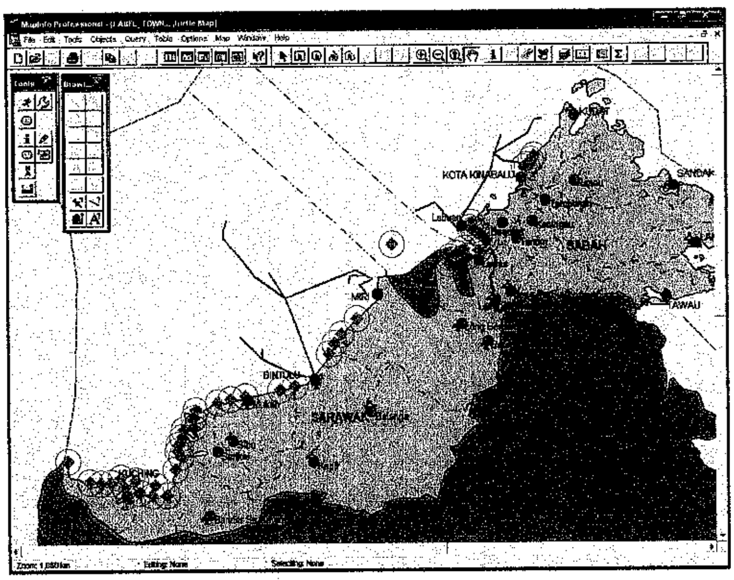

Figure 9: Map of crocodile.

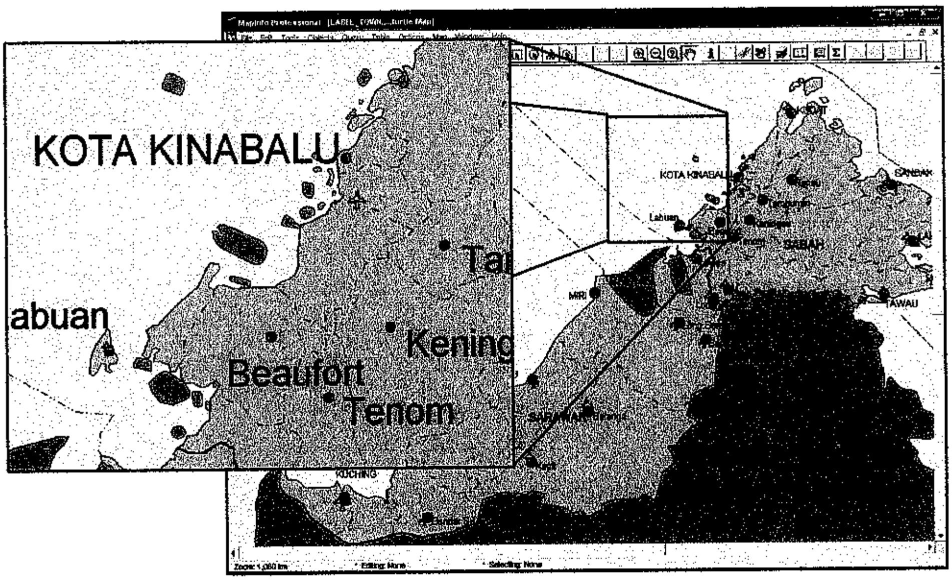

Figure 10: Map of fishing ground.

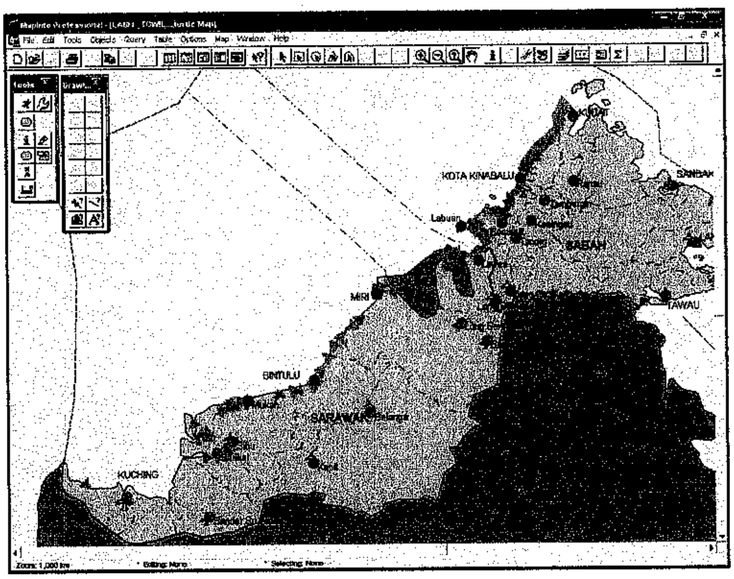

Figure 11: Map of mangrove.

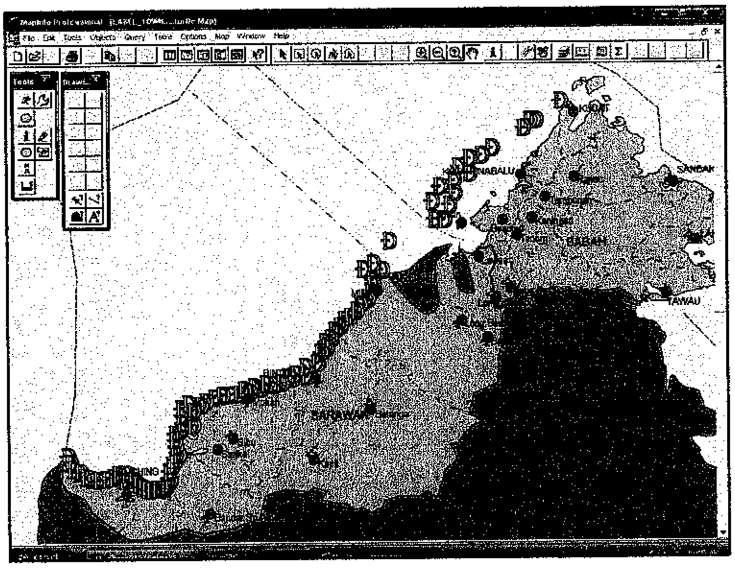

Figure 12: Map of dolphin.

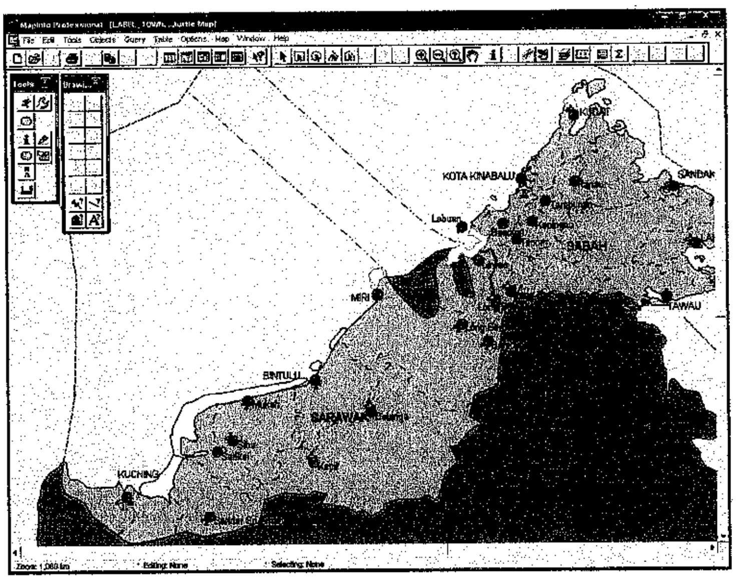

Figure 13: Map of prawn.

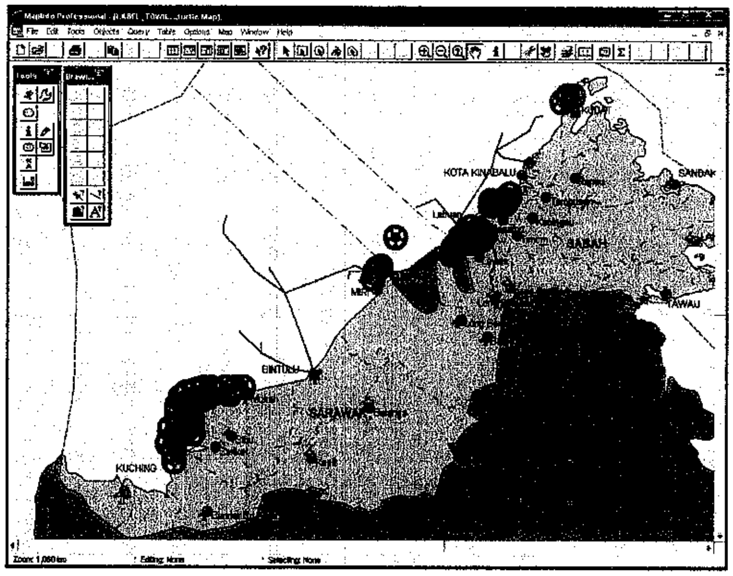

Figure 14: Map of shrimp.

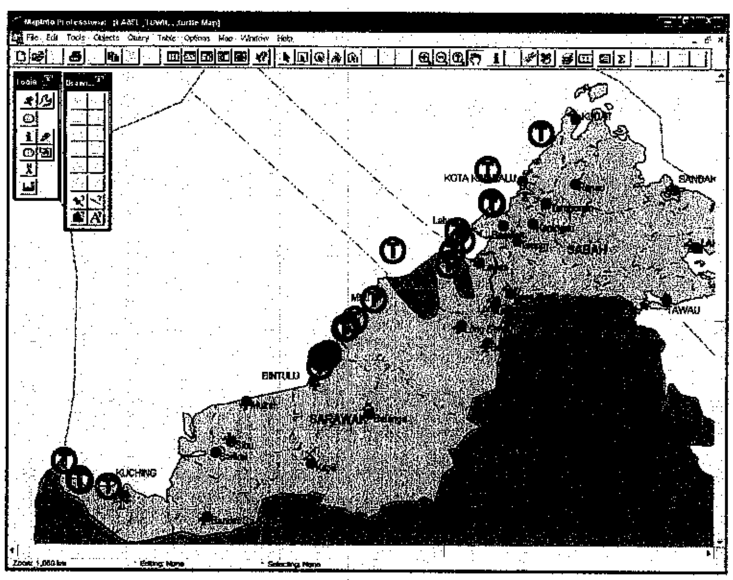

Figure 15: Map of turtle.

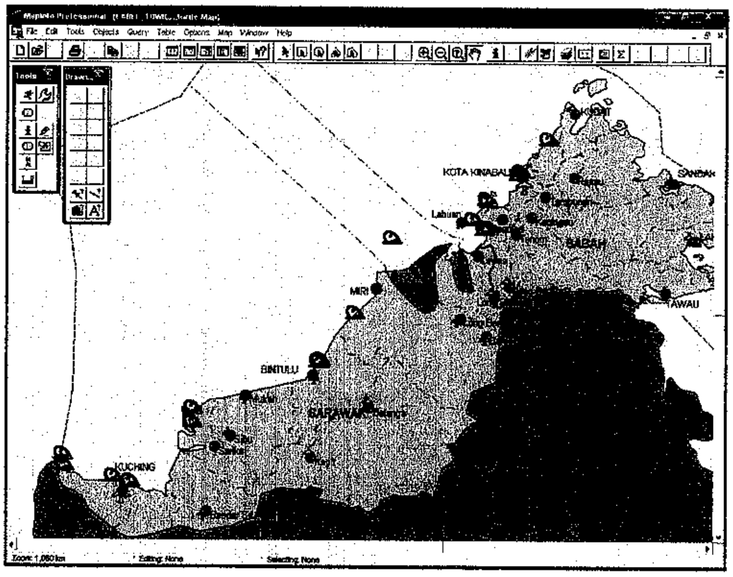

Figure 16: Map of wildlife.

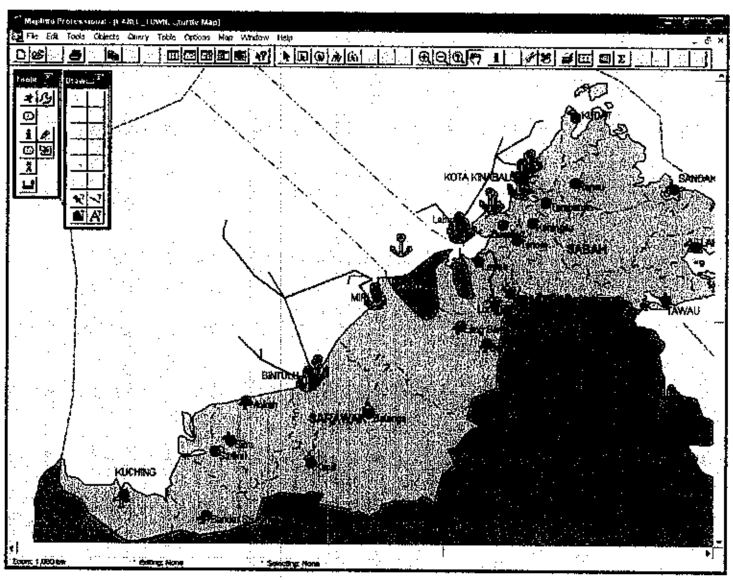

Figure 17: Map of tourism beach.

CHAPTER 5

RESULT & DISCUSSION

5.1 RESULT

5.1.1 Wind and current data.

The author use 2006 wind and current data provided by Malaysia Meteorology Department. Then, simplify into the table below for easy usage in spatial analysis.

Month	Wind Direction	Wind speed (m/s)	Current Direction	Current Speed (m/s)
JAN	193	99.4	249	3.5
FEB	37	19.0	100	4.3
MAR	115	59.2	77	3.3
APR	154	79.4	109	3.4
MAY	199	102.6	206	2.9
JUN	229	117.7	201	2.6
JUL	225	115.9	250	4.2
AUG	182	93.7	228	4.2
SEP	206	105.8	192	4.5
OCT	248	127.3	225	7
NOV	177	91.1	124	3.5
DIS	106	54.7	166	3.4

Table 1: Wind and Current Data for Sarawak Water

Month	Wind Direction	Wind Speed (m/s)	Current Direction	Current Speed (m/s)
JAN	86	44.2	153	2.6
FEB	40	20.6	152	5.2
MAR	113	58.1	85	3.7
APR	92	47.3	110	4.3
MAY	160	82.3	183	5
JUN	228	117.3	96	4
JUL	209	107.5	248	3.6
AUG	192	98.8	236	4.8
SEP	186	95.7	274	4.7
OCT	149	76.7	238	4.9
NOV	140	72.0	164	3.6
DIS	77	39.6	96	4.4

Table 2: Wind and Current Data for Sabah Water

5.1.2 Spatial Analysis

Spatial analysis was carried out base on the maximum and minimum speed of wind and current for both regions. Before any spatial analysis is carrying out, the author has developed the database for trajectory of oil on water.

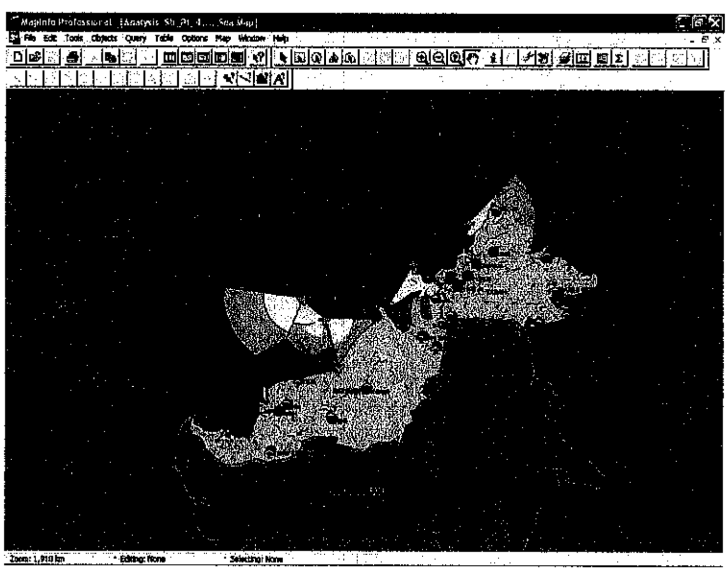

Figure 18: Trajectory of oil on water

5.1.2.1 **Sarawak Water.**

Scenario 1:

Leakage point : 4.85°, 112.24°
Wind speed : 4.6 m/s
Current speed : 7 m/s

Month : October
Wind direction : 247°
Current direction : 225°

Time (hrs)	Oil Slick Direction	Oil Slick Speed (m/s)	Oil Slick Distance (km)	Oil slick Location	
				Latitude	Longitude
1	224	4.90	17.50	4.7605	112.3480
6	224	4.90	105.30	4.1960	112.9015
12	224	4.90	210.00	3.5182	113.5645
18	224	4.90	315.80	2.8397	114.2233
24	224	4.90	421.00	2.1610	114.8848

Table 3: Oil trajectory data for scenario 1 at Sarawak water.

Scenario 2:

Leakage point : 4.85°, 112.24°
Wind speed : 5.7 m/s
Current speed : 3.4 m/s

Month : December
Wind direction : 106°
Current direction : 166°

Time (hrs)	Oil Slick Direction	Oil Slick Speed (m/s)	Oil Slick Distance (km)	Oil slick Location	
				Latitude	Longitude
1	169	3.30	11.90	4.7680	112.3325
6	169	3.30	71.70	4.2412	112.1088
12	169	3.30	143.30	3.6090	111.9808
18	169	3.30	215.00	2.9768	111.8528
24	169	3.30	286.70	2.3447	111.7268

Table 4: Oil trajectory data for scenario 2 at Sarawak water.

Scenario 3:

Leakage point : 4.73°, 112.71°

Month : Jun

Wind speed : 4.1 m/s

Wind direction : 228°

Current speed : 2.6 m/s

Current direction : 201°

Time (hrs)	Oil Slick Direction	Oil Slick Speed (m/s)	Oil Slick Distance (km)	Oil slick Location	
				Latitude	Longitude
1	200	2.50	9.00	4.6488	112.7453
6	200	2.50	53.80	4.2690	112.8818
12	200	2.50	107.60	3.8130	113.0453
18	200	2.50	161.40	3.3570	113.2088
24	200	2.50	215.30	2.9010	113.3720

Table 5: Oil trajectory data for scenario 3 at Sarawak water.

Scenario 4:

Leakage point : 4.73°, 112.71°

Month : November

Wind speed : 4.1 m/s

Wind direction : 177°

Current speed : 3.5 m/s

Current direction : 124°

Time (hrs)	Oil Slick Direction	Oil Slick Speed (m/s)	Oil Slick Distance (km)	Oil slick Location	
				Latitude	Longitude
1	122	3.40	12.30	4.6653	112.6238
6	122	3.40	74.00	4.3680	122.1535
12	122	3.40	148.10	4.0107	111.5895
18	122	3.40	222.10	3.6530	111.0262
24	122	3.40	296.20	3.2950	110.4632

Table 6: Oil trajectory data for scenario 4 at Sarawak water.

5.1.2.2 **Sabah Water**

Scenario 1:

Leakage point : 5.67°, 114.85°
Wind speed : 8.7 m/s
Current speed : 5.2 m/s

Month : February
Wind direction : 40°
Current direction : 152°

Time (hrs)	Oil Slick Direction	Oil Slick Speed (m/s)	Oil Slick Distance (km)	Oil slick Location	
				Latitude	Longitude
1	157	5.10	18.40	5.5240	114.7823
6	157	5.10	110.20	4.7763	114.4282
12	157	5.10	220.50	3.8788	114.0042
18	157	5.10	330.70	2.9812	113.5810
24	157	5.10	441.00	2.0833	113.1587

Table 7: Oil trajectory data for scenario 1 at Sabah water.

Scenario 2:

Leakage point : 5.67°, 114.85°
Wind speed : 5.7 m/s
Current speed : 5 m/s

Month : May
Wind direction : 160°
Current direction : 183°

Time (hrs)	Oil Slick Direction	Oil Slick Speed (m/s)	Oil Slick Distance (km)	Oil slick Location	
				Latitude	Longitude
1	184	4.80	17.40	5.5170	114.8638
6	184	4.80	104.60	4.7340	114.9158
12	184	4.80	209.20	3.7947	114.9782
18	184	4.80	313.90	2.8552	115.0403
24	184	4.80	418.50	1.9157	115.1023

Table 8: Oil trajectory data for scenario 2 at Sabah water.

Scenario 3:

Leakage point : 6.63°, 116.19°
Wind speed : 7.2 m/s
Current speed : 2.6 m/s

Month : January
Wind direction : 86°
Current direction : 153°

Time (hrs)	Oil Slick Direction	Oil Slick Speed (m/s)	Oil Slick Distance (km)	Oil slick Location	
				Latitude	Longitude
1	158	2.50	9.10	6.5600	116.1580
6	158	2.50	54.50	6.1822	116.0083
12	158	2.50	109.00	5.7287	115.8123
18	158	2.50	163.60	5.2752	115.6243
24	158	2.50	218.10	4.8217	115.4365

Table 9: Oil trajectory data for scenario 3 at Sabah water.

Scenario 4:

Leakage point : 6.63°, 116.19°
Wind speed : 4.1 m/s
Current speed : 4.0 m/s

Month : Jun
Wind direction : 228°
Current direction : 96°

Time (hrs)	Oil Slick Direction	Oil Slick Speed (m/s)	Oil Slick Distance (km)	Oil slick Location	
				Latitude	Longitude
1	95	4.10	14.70	6.6247	116.0568
6	95	4.10	88.20	6.5695	115.3932
12	95	4.10	176.40	6.5023	114.5972
18	95	4.10	264.60	6.4340	113.8013
24	95	4.10	338.10	6.3760	113.1382

Table 10: Oil trajectory data for scenario 4 at Sabah water.

5.2 DISCUSSION

5.2.1 Sarawak Water

Scenario 1:

In scenario 1, the maximum speed of current is chosen to be used. This happened to be in the month of October. The leakage point is assume to be at location 4.85 N 112.34 E. from the data provided by meteorological department, wind blow frequently may be occur at 247° and current direction at 225°.

Base on data, the speed of wind varies from 10.8 m/s to 1.54 m/s. The speed of current varies from 15.6 m/s to 3.1 m/s. For this project, the author used the average speed value for both. The speed of wind is 4.6 m/s and the speed of current is 7 m/s. From the Oil on Water Trajectory calculator, oil slick may be travel at speed 4.9 m/s at direction 224°. So, the oil slick probably moves toward South – West direction.

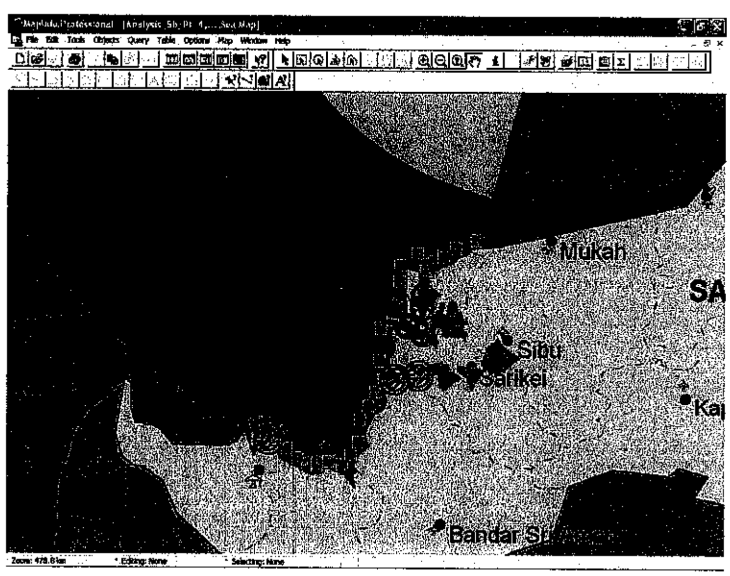

Figure 19: Damage area for 1st leakage scenario on Sarawak water

Within 1 hour, the oil slick may travel 17.5 Km from the leakage point. After 6 hours, it may reach 105.3 Km away from the original position. This is nearly 6 time distance than the first hour leakage. The oil slick probably travel 143.3 Km after 12 hours leakage. After 18 hours, the oil slick may reach the shore of Sarikei district and followed by the shore of Bandar Sri Aman about 24 hours after leakage. The distance after 24 hours leakage is 286.7 Km. if the speed and direction of oil slick trajectory maintain, the shore of Kuching may affected by the leakage at 25th hours.

The leakage may cause damage to the marine habitat, flora and fauna along Sareikei and Bandar Sri Aman shoreline. This will result in damaging the shrimp habitat which is 30 – 40 Km away from the shore. There are about 21 location of shrimp and dolphin that effected by the oil slick. Within 18 – 24 hours, 3 aquaculture locations may be damaged by the oil slick.

The crocodile habitat also may be damaged after 18 hours of leakage. There are 14 habitats in the river along the affected areas. The mangrove forest also may be covered by oil slick. This may cause more serious damage because mangrove forest is habitat to a lot of fauna and insect.

Scenario 2:

For the second scenario, the location of the leakage is assumed to be the same as first scenarios. But, the different is the direction and speed of the wind and current. The maximum average wind speed is taken into account. In December, the average speed of wind is 5.7 m/s and average speed of the current is 3.4 m/s which are lower than the speed of wind.

The observation made by meteorological department show that the maximum speed of wind can reach up to 11.3 m/s on 29th of December. While, the current speed are varies between 1 – 4.7 m/s. The wind moving to the direction 106° while the current move toward 166° to South South – East direction. The direction is quite perpendicular to the shoreline. Therefore, the oil slick may propagate towards the Mukah and Bintulu shoreline.

The result from Oil on Water Trajectory calculator show that the oil slick travel in the direction 169°, nearly in south direction. It travels with the speed of 3.30 m/s. This speed is a little bit lower than the current speed. With this speed, the oil slick can travel to nearly 12 Km from the leakage point within one hour. For the next 6 hours, it travel 71.7 km further to 143.3 km in 12 hours. The distance travel by the oil slick increase to 143.3 km in 18 hours which is nearly double the 12 hour distance.

The oil slick may reach 90% of the shore area within 12 hours to 18 hours after leakage. This is much faster than the first scenario which takes nearly 24 hours to reach shore. This scenario cause more damaging to the environment because of the oil slick direction. Therefore, the oil slick may directly hit the shore because it movement direction nearly perpendicular to the shoreline. So, the affected area is more broad compare to the first scenario.

Coral reef is the first marine habitat that is affected by the leakage. It is occur about 9 hours after the leakage. There are 5 major area and 4 small area of coral reef that overlaid by the oil slick in just 12 hours. This can cause a lot of damage to coral reef in the area. From the spatial analysis, the endanger marine habitat is dolphin. There are 23 habitat of dolphin that affected by the leakage.

The leakage also could damage the 12 habitat of shrimp which is located near the Sarikei shore. Crocodile habitat also affected along with 8 habitat of crab. Near the Bintulu shore are, 4 habitat of turtle also affected and most of the mangrove are that involve has a lot of habitat of shore bird. From the map, the author can identify 9 habitats of them.

Although the leakage location is the same, but the damage causes by the leakage is greater than he first scenario. It may cause by the direction of oil slick movement anf the speed of it which take less than 24 hours to reach the shore.

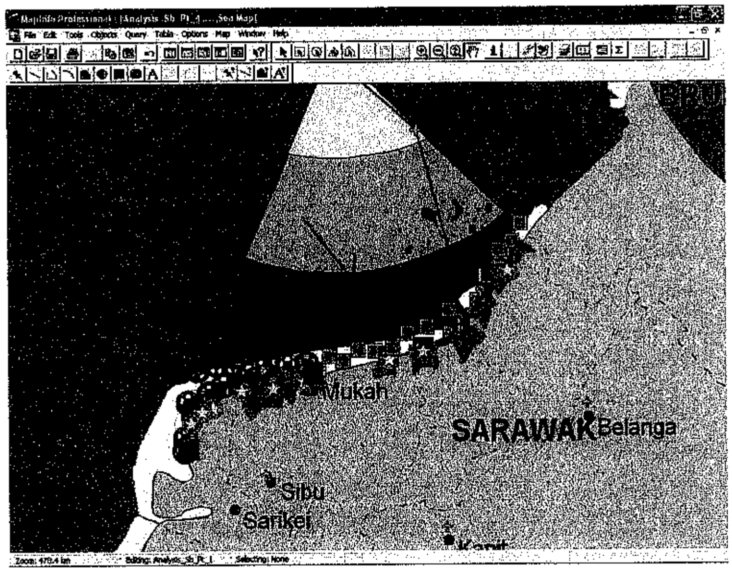

Figure 20: Damage area for 2nd leakage scenario on Sarawak water

Scenario 3:

In this scenario, the author assume the leakage take place at the location of 4.73° N 112.71° E. data selected is the average minimum speed of current speed. This speed recorded in the month of Jun. from the daily data, the speed of the current varies from 1.6 m/s to 4.7 m/s. the wind speed varies from 6.69 m/s to 0.514 m/s. in spatial analysis, the author used the average speed data for the month which is 4.1 m/s for wind and 2.6 for he current. The wind blow toward South – West; 228° from North. While the current propagate toward South South – West; 210° from North.

The resultant direction for the oil slick is 200° towards South South – West. The speed of the oil slick is 2.5 m/s. this speed is much slower than any of previous scenario. This could cause by the speed of current which is much slower than before. The movement slick direction is preventing the Mukah shoreline from being hit directly by the leakage oil. The oil slick propagation need more time to reach the shore compare to previous scenario.

At first hour, the oil slick propagates to 9 km away from the leakage point. After 6 hours, the distance increase up to 53.8 km. then, the oil slick reaches the shore at 18 hour after leakage. But the affected area only about 30 – 40 % from total damage area. After that, the oil slick has covered the remaining of the Mukah shoreline. so, within 24 hours, the oil slick has travel about 215 km. this is may cause by the location of leakage is quite near the shore, so the time taken to travel is less.

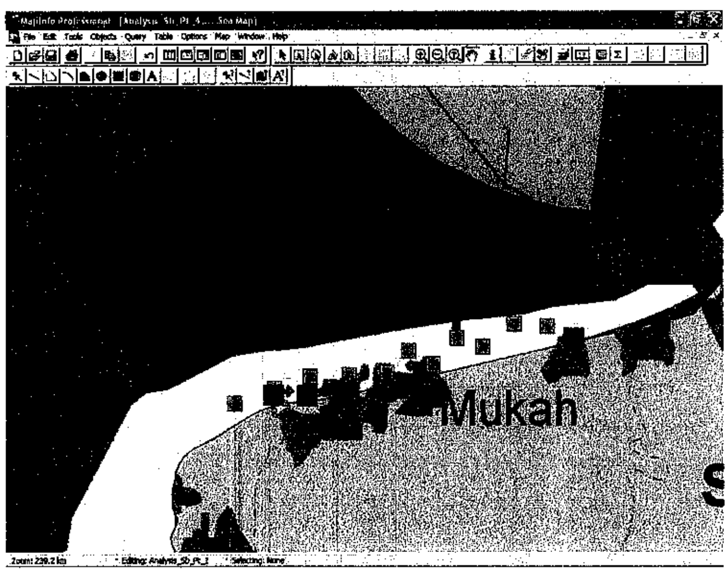

Figure 21: Damage area for 3rd leakage scenario on Sarawak water

Mukah coastal area has a huge density of prawn habitat. So, this species is the most affected by the leakage. Then followed by the dolphin habitat in 12 location that affected by the leakage. Two habitats of corral species also affected after 18 hours after leakage. The other species that endanger is 4 habitats of crocodile and 4 habitat of crab.

After 24 hours propagate, the oil slick may cover 943 km2 area of the mangrove forest. This can cost a lot of money to clean up the oil from the mangrove area. It is become more difficult because the mangrove forest is habitat for many species of fauna.

Scenario 4:

The leakage location for this scenario is similar to the 3rd scenario; at 4.73° N 112.71° E. but, the data for November is used for this scenario. It is because this month has the average minimum wind speed which is 4.1 m/s. From daily observation made by Meteorological Department, the wind speed for November varies from 9.77 m/s to 1.54 m/s. The current speed varies from 1.6 m/s to 4.7 m/s. The average speed of current is 3.5 m/s. In November, wind blow in the direction of 177° while current flow 124° towards East South – East.

The resultant direction is 122° toward East South – East. It is nearly same as current direction. The oil slick speed is 3.4 m/s. this speed is higher than the 3rd scenario where the oil slick speed is only 2.5m/s. this is may be result from the higher current speed in November compare to Jun.

The first hour of leakage, the oil slick travel 12.3 km away from leakage point. The next 6 hours it travel more further to74 km. in the 12 hours of leakage, the oil slick already reach 148.1 km distance from it origin. The distance increase up to 222.1 km in 18 hour and in 24 hours it distance up to 296.2 km. compare to the scenario 3, oil slick for scenario 4 travel more further than in scenario 3. This may be cause by the high current speed which results in high oil slick speed also. Thus, the oil slick speed may be proportional to current speed.

From the spatial analysis, the oil slick only takes less than 12 hours to reach the shore. This is the fastest time compare to the previous scenario. This situation may be as a result from the speed of the oil slick. Plus the direction of oil slick is nearly perpendicular to the shore. The most affected area is the shoreline between Miri and Bintulu. The distance is about 165 km.

Within 6 hours of leakage, the oil slick encounters 5 location of coral reef. 3 of the location is the major area for coral reef habitat. There are 2 location of prawn habitat that directly affected. One of the habitats is located near Bintulu and the other one is located between Miri and Bintulu. In this affected region, there are 6 location of turtle habitat. Then, there are also 12 habitat of dolphin and 2 habitat of crab.

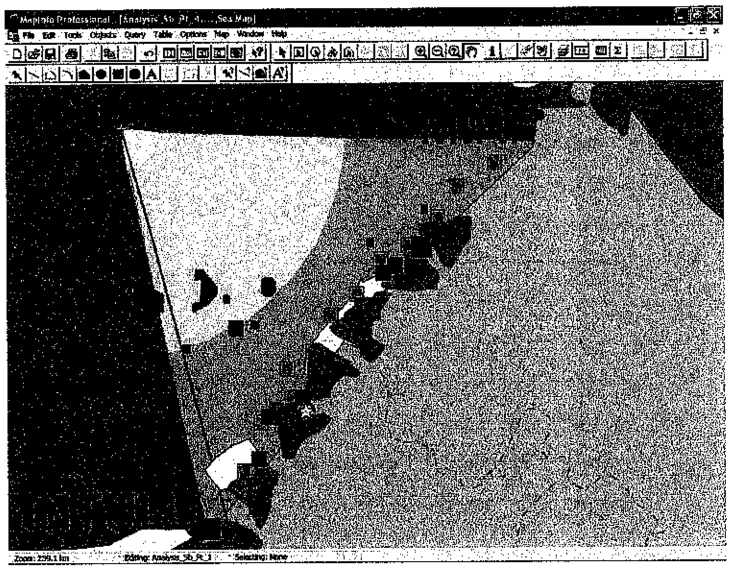

Figure 22: Damage area for 4th leakage scenario on Sarawak water

5.2.2 Sabah Water

Scenario1:

The first location for leakage point at Sabah water is 5.67° N 114.85° E. this location is located 52 km away from Labuan. The data selected from month of February because of the high average wind speed. The wind speed is varies from 5.1 m/s to 11.3 m/s. the wind speed at this location is quite higher than Sarawak water. The current speed is varies from 3.1m/s to 7.8 m/s. The average wind speed is 8.7 m/s. The average current speed for the month is 5.2 m/s. the wind blow in the direction of 40° while the current flow in the direction of 152°.

The resultant direction for oil slick is 157° toward South South – East. With the above wind and current parameter, the oil slick propagates with the speed of 5.10 m/s. This is the highest speed of oil slick compare to previous spatial analysis at Sarawak water. From the previous scenario, the oil slick speed usually slightly lower than current speed. But for this condition, the oil slick speed is much higher than current speed. This condition may cause by the high speed of current flow plus the high speed of wind blow. The wind added more force to the oil slick and therefore increase it speed.

Within one hour, the oil slick travel 18.4 km toward the shore. After 6 hours of leakage, the oil slick is 110.2 km and travel further to 220 km within 12 hours after leakage. Due to the leakage location which is not far from the shore, the oil slick takes less than 6 hours to reach the shore.

The damage can cause a lot of damage to environment because the area that affected by the leakage is dense with marine life and mangrove forest. Labuan Island takes the impact before the oil slick reach the Sabah shore. At Labuan Island, there are 4 tourism beaches surrounding the island. The oil may contaminate the beach. Therefore, this situation may cause the beach closed to the public. It is for cleaning purposed. Thus, the economic activity need to be stop and cause loses to the business owner.

The oil may damage the surface reef near the Labuan Island. There are 2 area of surface reef and each one is about 16 km^2 and $24km^2$. there are 2 area of coral reef in the affected region. The first one is near the leakage point. So, the oil slick already hit it in first hour after leakage. The other one is near Labuan Island and international border. Marine life that affected in the region is shrimp. There is 13 location of shrimp habitat in the map. The location consists of a wide mangrove forest. So, there are 15 habitat of shore bird in it. The prawn habitat also affected by the oil slick.

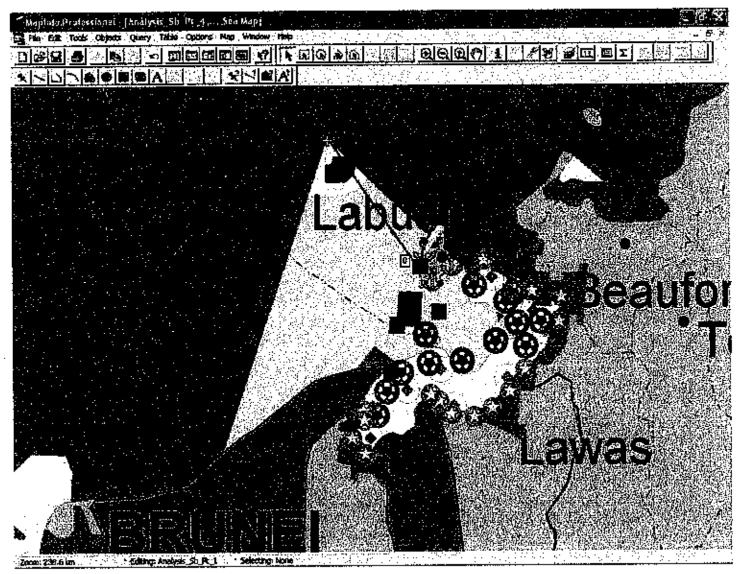

Figure 23: Damage area for 1st leakage scenario on Sabah water

Scenario 2:

In this scenario, the location of leakage is similar to the first scenario in Sabah water. The location is 5.67° N 114.85° E. the data use for this scenario is May data. In May, the speed of the current is quite high; therefore the authors choose to use it. The wind speed are varies between 2.57 m/s to 10.28 m/s. while the current speed varies from 3.1 m/s to 7.8 m/s. the average wind speed is 5.7

m/s and the current speed is 5 m/s. wind blow in the direction of 160° while the current propagate in the direction of 183°.

From the Oil on Water Trajectory calculator, the resultant oil slick speed is 4.8 m/s. This is lower than the first scenario. It may be because the wind speed is only 5.7 m/s. the oil slick travel in the direction of 184° in South direction. In the first hour after leakage, the oil slick travel with the distance 17.4 km. after 6 hours, the oil slick travel 104.6 km away from the leakage point.

Figure 24: Damage area for 2nd leakage scenario on Sabah water

The oil slick reaches the shore less than 6 hours. This is because the distance between leakage point and the shore is quite near. Most of the impact may be occur in Brunei territory. The author has no data regarding marine life and mangrove forest in Brunei. In the first hour, the oil slick may damage the coral reef because there is a coral reef habitat near the oil leakage. Beside that, a dolphin habitat also present near the pipeline leakage. So, both marine life may be the first habitat affected by the oil slick in this scenario.

There are 7 shrimp habitat present in the affected area. This is nearly half of number compare to affected shrimp habitat in the first scenario. Then, 8 of shore bird habitat also affected by the leakage. At the same time, mangrove forest near Lawas also affected by the leakage this including 3 habitats of turtle. The prawn habitat affected is half from the first scenario. This is because the propagation of oil slick is more toward Brunei shore line.

<u>Scenario 3:</u>

The author assumes the third leakage location at 6.63° N 116.19° E. this location is about 30 km from the shore. The authors choose the data of the January because in this month the lowest average current speed occurs. From raw data given by meteorological department, wind speed in this month varies from 2 m/s to 8.23 m/s. The current speed varies from 3.1 m/s to 7.8 m/s. So, the average wind speed is 7.2 m/s while the average current speed is 2.6 m/s. In this scenario, the speed for both parameters is opposite which is the wind speed is high while the current speed is quite low.

The wind blow in the direction of 86° and the current propagate in the direction of 153°. So, the resultant direction for the oil slick is 158° to South South – East. The speed of the oil slick is 2.5 m/s. Due to the location of leakage near shore, the oil slick may take a short time to reach the shore although the oil slick travels at lower speed. In 1 hour, the oil slick has travel 9.1 km from the leakage point. For the next 6 hours, the travel distance increase to 54.5 km. This mean the oil slick already reach the shore.

At the first hour of leakage, the oil slick has affected 3 location of coral reef and propagates toward 2 more coral reef location. The average area of coral reef is about 2 km^2. In the affected region, there are 3 location of aquaculture where one of it located near Kuching. Tourism beach also affected by the leakage, so, may be 3 tourism beaches need to be closed to public for clean up process. This may create a trouble in local business in that area due to lack of tourist.

There are 3 surface reef locations in the affected area. The biggest one is about 70 km^2. The oil slick may damage the fishing ground for the fisherman. There are 3 fishing ground in the affected area where the big area is about 20 km2. Besides that, 5 habitat of crap also endanger because it located in the affected area. The other habitat that affected is mangrove forest, 7 habitat of shore birds, 4 habitats of crocodile and 1 wildlife habitat.

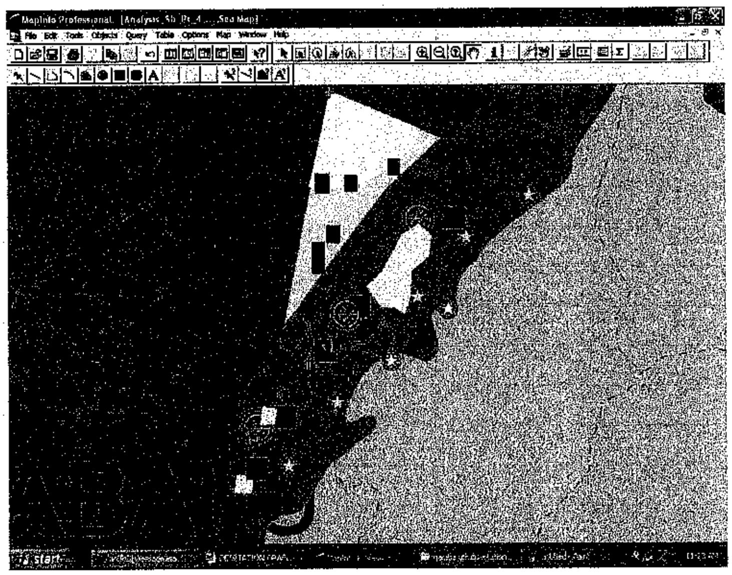

Figure 25: Damage area for 3rd leakage scenario on Sabah water

Scenario 4:

The leakage point for the forth scenario is similar to the third scenario. The leakage located at 6.63° N 116.19° E. On the month of Jun, the wind speed varies from 3.6 m/s to 9.77 m/s. The current for this month varies from 1.6 m/s to 7.8 m/s. The average speed of wind is 4.1 m/s while the average speed of current is 4.0 m/s. Both speeds are nearly similar. The direction of wind blow is 228° and the direction of current is 96°. So, the resultant direction for the oil slick is 95° which is less 1° than current direction. The speed of the oil slick is 4.10 m/s.

For the first hour of leakage, the oil slick travel 14.7 km away from the leakage point. Then it travel with distance 88.20 after 6 hours. Because of the distance between leakage point and the shore is short, the oil slick has reach the shore about 4 hours after leakage. In the first hour leakage, the oil slick has reach 2 aquaculture location and 1 area of surface reef. Then the oil slick propagate trough 8 coral reef location and then hit the mangrove forest. The other marine life that affected is crab and shrimp.

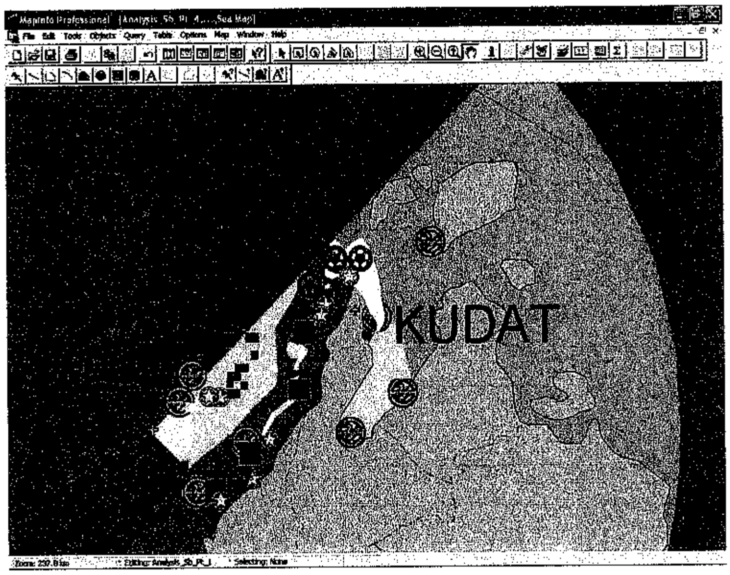

Figure 26: Damage area for 4th leakage scenario on Sabah water

CHAPTER 6
CONCLUSION

Based on the eight spatial analysis perform by the author, the oil slick speed and direction are dominantly influence by the current speed and direction. However, the wind speeds also give a big influence in oil slick speed if the wind speed is high enough, may be double than current speed.

The factors that determine the level of damage are direction of the oil slick and the density of marine habitat or flora and fauna at the respective location.

The worse case scenario from the spatial analysis is the second scenario at the Sarawak water. The oil slick propagates directly toward the shore in less than 18 hours. It may contaminate 297 km of shoreline in that duration. The oil slick may damage 7 marine life habitats, coral reef area and mangrove forest along the shore.

REFERENCES

1. Mohd Nizam Basiron, *Protection of the Marine Environment from Sea-Based Pollution*, Research Fellow, Centre for Coastal and Marine Environment Maritime Institute of Malaysia.

2. Sea Empress Environmental Evaluation Committee (SEEEC), *The Environmental Impact of the Sea Empress Oil Spill.*

3. W. D. Mc Cain, Jr. *The properties of petroleum fluids*, Penn Well Publication second edition. Journal of Petroleum Technology, Society of Petroleum Engineers.

4. Dr. Brian Dicks, *The Environmental Impact of Marine Oil Spill*, Technical Team Manager, International Tanker Owners Pollution Federation Ltd, 6th November 1998, Rio De Janeiro, Brasil.

5. Dean E. Gaddy, 2003, *Introduction to GIS Petroleum Industry*, Penn Well Publication.

6. P. Pascolo & C.A. Brebbia, 1998, GIS Technologies and Their Environmental Applications, WIT Press Southampton, Boston.

7. Laura Lang, *Managing Natural Resource with GIS*, ESRI Press.

8. R.W. Greene, *Confronting Catastrophe – A GIS Handbook*, ESRI Press.

9. Larry Daniel, Paula Loree & Angela Whitener, Inside Map Info Professional, 3rd edition, Onword Press.

10. NOAA's National Ocean Service Office Response and Restoration http://response.restoration.noaa.gov.

11. Environment Informatics Achieve < http://www.iseis.org/eia/contents.asp?sn=2>.

12. Mineral Management Service, Gulf of Mexico region < http://www.gomr.mms.gov/index_common.html >.

APPENDICES

Jabatan Meteorologi Malaysia

Sabah Water

Period : 2006

Range :

Latitude - 1.5 to 4.5 N

Longitude -109.0 to 114.33 E

Year	Month	Day	ObsTime (UTC)	Latitude (degree)	Longitude (degree)	Wind Direction (degree)	Wind Speed (knots)	Wave Period (sec)	Wave Height (metre)	Primary Swell Direction (degree)	Primary Swell Period (sec)	Primary Swell Height (metre)	Wave Length (m)
2006	01	04	00	7.3	119.0	050		5	1.5	050	6	1.5	39.0
2006	01	06	00	7.1	116.0	070	18	4	1.0	040	7	1.5	25.0
2006	01	09	12	6.3	115.1	010	10						0.0
2006	01	10	12	6.7	115.2	040	19						0.0
2006	01	10	18	7.2	115.8	040							0.0
2006	01	11	00	6.5	115.0	050	11	4	0.5	090	11	1.0	25.0
2006	01	11	18	7.1	116.0	020	19	2	1.5	010	5	2.0	6.2
2006	01	13	06	7.2	115.3	050	9	2	0.5	350	4	1.0	6.2
2006	01	20	12	6.7	115.2	230	14						0.0
2006	01	23	00	7.5	115.9	030	16	1		200	1	1.0	1.6
2006	01	25	00	7.5	115.8	010		0	0.0	350		0.5	0.0
2006	01	25	06	7.2	115.7	300	12	1	0.5	010	2	1.0	1.6
2006	01	25	18	7.2	116.2	220	7	1	0.5	280	6	1.0	1.6
2006	02	03	00	7.1	115.6	010	15	0	0.0	070	3	1.5	0.0
2006	02	10	00	7.2	115.2	070		5	0.5	050	12	1.5	39.0
2006	02	11	00	7.5	116.5	040	10	3	1.0	350	8	3.0	14.1
2006	02	22	12	7.2	115.6	040	20						0.0
2006	02	24	06	6.3	115.1	040		0	0.0	040	2	0.5	0.0
2006	02	25	00	6.6	115.2	040	22	2	1.5	250	3	1.5	6.2
2006	03	07	12	7.4	115.8	160	8						0.0
2006	03	08	06	4.4	117.8	230	12	1	0.5				1.6
2006	03	10	12	6.2	115.0	180	4	1	0.5				1.6
2006	03	10	18	6.4	115.0	040	8	3	1.0	030	6	2.0	14.1
2006	03	11	00	7.4	116.4	270	2	1	0.5	030	6	2.0	1.6
2006	03	15	06	6.7	115.2	030	8	0	0.0	190	2	0.0	0.0
2006	03	18	12	7.0	115.9	090	10	3	1.0				14.1
2006	03	22	00	7.5	116.0	070	17	4	2.0	080	4	2.0	25.0
2006	03	23	12	7.0	115.5	060	15						0.0
2006	03	23	12	7.2	115.6	080	15						0.0
2006	03	26	00	7.5	115.9	080		2	0.5	060	2	1.0	6.2
2006	03	27	00	7.5	115.7	030	16	3	1.0	050	3	1.0	14.1
2006	03	28	12	6.7	115.4	220	9	2	1.0	190	4	1.0	6.2
2006	03	29	18	7.1	115.1	070	23	4	1.5				25.0
2006	03	31	06	7.2	115.4	090	12	0	0.0	050	2	0.5	0.0
2006	04	05	00	7.5	116.1	250	5	2	0.5	040	4	0.5	6.2
2006	04	05	06	6.7	115.3	080	10	2	0.5	020	3	1.0	6.2
2006	04	05	12	6.8	115.4	060	17						0.0

2006	04	08	12	7.3	116.2	270	10	8	1.0				99.9
2006	04	09	00	6.7	115.2	060	15		0.5	090	1	0.5	0.0
2006	04	10	18	7.5	116.1	100	12	2	0.5	090	3	0.5	6.2
2006	04	12	12	6.1	119.2	000	0						0.0
2006	04	12	18	7.3	118.7	050	8		0.5				0.0
2006	04	14	00	7.5	115.9	090	6	0	0.0	080	2	0.5	0.0
2006	04	16	00	7.2	115.3	040	10	3	1.5	210	3	1.5	14.1
2006	04	16	06	7.5	115.8	020	7	2	1.0	200	2	1.0	6.2
2006	04	22	00	6.8	115.7	080	6	1		220	5	1.0	1.6
2006	04	24	00	7.3	115.7	110	15	2	1.5				6.2
2006	04	25	00	7.5	115.9	080	16	3	1.5	040	3	1.0	14.1
2006	05	01	12	7.1	115.9	110	6	2	0.5	140	4	1.0	6.2
2006	05	02	18	6.7	115.2	010	5						0.0
2006	05	11	00	6.8	115.5	090	9	2	0.5	000	0	0.0	6.2
2006	05	17	00	7.5	116.7	210	13	5	1.5		5	1.5	39.0
2006	05	17	06	7.0	115.0	270	13	4	1.0	270	4	1.5	25.0
2006	05	19	18	7.3	116.3	140	6	2	0.5	350	5	0.5	6.2
2006	05	22	06	6.8	115.3	330	10	3	1.5	030	4	1.5	14.1
2006	05	25	18	6.9	115.8	090	20	5	2.0	180	5	1.5	39.0
2006	05	26	12	7.5	116.4	100	20	3	1.5	090	5	1.5	14.1
2006	05	29	00	7.4	115.5	230	10	3	1.0	220	3	1.0	14.1
2006	05	30	00	6.9	115.4	180	11	0	0.0				0.0
2006	06	05	06	7.1	116.3	190	10	0	0.0	050	5	0.5	0.0
2006	06	05	12	7.4	116.6	260	4	3	1.0	100	2	1.0	14.1
2006	06	05	18	6.5	115.3	260	4	2	0.5	100	2	1.0	6.2
2006	06	08	00	7.5	115.8	140	6	2		070	2		6.2
2006	06	10	06	7.5	115.8	260	8						0.0
2006	06	10	06	7.5	115.8	260	8						0.0
2006	06	10	18	6.6	118.7	270	8	3	0.5	090		0.5	14.1
2006	06	10	18	6.6	118.7	270	8	3	0.5	090		0.5	14.1
2006	06	10	18	6.7	115.3	270			0.5	000		1.0	0.0
2006	06	13	18	6.7	115.4	160	5	1	0.5	200	4	1.0	1.6
2006	06	15	00	7.0	115.3	190	8	2	1.0				6.2
2006	06	16	00	7.3	115.5	160	2	2	1.0	010	1	0.5	6.2
2006	06	23	00	7.0	115.9	230	9	3	0.5	200	5	1.0	14.1
2006	06	25	00	6.9	115.4	330	16	3	0.5	020	2	0.5	14.1
2006	06	26	06	6.6	115.2	170		2	0.5	130	3	3.0	6.2
2006	06	28	18	7.3	115.8	250	9						0.0
2006	06	29	06	6.4	117.4	200	12	5	2.0	190	6	2.5	39.0
2006	07	03	00	5.6	118.6	220	10	0	0.0				0.0
2006	07	06	00	7.3	115.7	120	6			250	2		0.0

2006	07	07	00	7.5	116.9	250	7	3	1.0	240	3	1.0	14.1
2006	07	07	06	7.2	115.5	210	13	2	1.0	180	4	2.0	6.2
2006	07	08	00	7.4	116.6	170		2	0.5	290	7	1.0	6.2
2006	07	11	06	6.8	115.6	190	8		0.5	290	9	1.0	0.0
2006	07	18	00	6.7	115.3	210	10	2	1.0	230	4	1.0	6.2
2006	07	20	00	7.5	115.8	350	9	1	1.0	300	3	1.5	1.6
2006	07	20	06	6.3	115.0	180	8	2	1.5	300	3	1.5	6.2
2006	07	20	18	7.4	119.0	260		3	0.5	200	4	0.5	14.1
2006	07	21	18	6.5	115.2	260	20						0.0
2006	07	22	18	7.4	115.8	200	19						0.0
2006	07	23	00	6.5	115.1	210	9	3	1.0	210	3	1.0	14.1
2006	07	24	12	6.3	115.1	150	19						0.0
2006	07	24	18	7.2	116.1	040	10						0.0
2006	07	26	00	6.3	115.0	300	4			240	2	1.0	0.0
2006	07	26	12	6.9	115.4	220	10						0.0
2006	07	29	12	7.2	115.5	230	12	3	1.0	240	0	0.5	14.1
2006	08	06	06	7.0	115.5	200	15	2	0.5	260	5	1.5	6.2
2006	08	07	00	7.4	115.7	230	21	3	1.5	220	4	2.0	14.1
2006	08	08	06	6.7	115.5	210	8		1.0	220	5	2.0	0.0
2006	08	08	06	7.5	115.8	220	25	4	2.5	240	6	2.5	25.0
2006	08	09	18	7.2	115.5	060	6	10	4.0				156.1
2006	08	13	18	7.4	116.5	200	6	2	0.5	270	5	1.5	6.2
2006	08	14	06	7.4	116.4	250	4		0.5	230	6	2.0	0.0
2006	08	14	12	6.6	115.1	230	8	4	0.5	240	6	1.0	25.0
2006	08	15	00	7.4	115.8	120	6			070	5	0.5	0.0
2006	08	15	06	6.8	115.6	000	4			270	6	2.0	0.0
2006	08	16	06	7.1	115.4	130	6	1					1.6
2006	08	17	18	6.9	115.4	320	13						0.0
2006	08	17	18	7.5	115.8	090	5						0.0
2006	08	22	12	7.5	115.7	240	21						0.0
2006	08	24	00	7.5	115.9	180	12	2	0.5	270	4	1.0	6.2
2006	08	24	06	6.5	115.0	200	12	2	1.0	270	3	1.0	6.2
2006	08	28	00	7.3	115.7	240	7	2	0.5	250	3	1.0	6.2
2006	08	29	18	7.3	115.5	360	3	2	0.5				6.2
2006	08	31	00	6.8	115.3	160	4			260	1	0.5	0.0
2006	09	01	00	6.4	115.1	230	9	3	0.5	320	3	1.0	14.1
2006	09	07	06	6.8	115.3	040	3	2	0.5	220	2	0.5	6.2
2006	09	10	18	6.6	115.1	140	3	0	0.0				0.0
2006	09	11	00	6.5	115.4	000	0	0	0.0				0.0
2006	09	12	06	7.4	115.8	180	26			270	3	1.0	0.0
2006	09	14	06	7.1	115.7	360	11	3	1.5	340	2	1.0	14.1

2006	09	14	12	6.9	118.3	000	4						0.0
2006	09	18	00	6.5	115.1	180	9	3	1.0	250	5	1.5	14.1
2006	09	18	06	7.5	116.6	270	15	4	1.0	250	4	1.0	25.0
2006	09	19	00	7.5	115.8	240							0.0
2006	09	21	06	6.7	115.2	270			0.5	000			0.0
2006	09	21	12	7.1	115.6	220							0.0
2006	09	28	06	7.3	115.7	250	18	3	1.5	300	3	1.5	14.1
2006	09	30	06	7.2	116.2	230	13	2	0.5	240	4	1.0	6.2
2006	10	01	18	6.7	115.2	230	6						0.0
2006	10	03	00	7.4	115.4	220	10	5	0.5	000		0.0	39.0
2006	10	03	06	6.8	115.4	030	12	1		220	1	0.5	1.6
2006	10	10	06	5.5	117.0	130	11	3	1.0	130	3	1.0	14.1
2006	10	10	12	7.1	116.5	070	12						0.0
2006	10	11	18	7.5	116.4	250		6	3.0	240	9	2.0	56.2
2006	10	12	00	7.3	115.5	220	15	2	0.5				6.2
2006	10	12	06	7.1	115.2	250		4	1.0	230	7	1.5	25.0
2006	10	12	12	7.3	116.0	250	12						0.0
2006	10	14	18	6.4	115.0	010	9						0.0
2006	10	14	18	7.2	115.8	260		2	1.0				6.2
2006	10	20	18	6.9	115.5	060	5						0.0
2006	10	25	18	6.4	115.0	040	8						0.0
2006	10	26	18	6.5	115.0	040	6	2	0.5	340	3	0.5	6.2
2006	10	31	00	7.4	115.7	180	14	3	0.5	270	5	1.5	14.1
2006	11	01	00	7.3	115.6	220	12	2	1.0	220	2	1.0	6.2
2006	11	01	05	7.4	115.3	220	14	2	1.0	250	3	1.0	6.2
2006	11	02	00	6.5	115.2	210	11						0.0
2006	11	02	00	6.9	115.4	230	2	3	0.5	230	3	1.0	14.1
2006	11	02	00	6.9	115.7	200	6	2	0.5	290	5	1.0	6.2
2006	11	04	18	6.4	115.1	070	6						0.0
2006	11	05	00	7.1	115.3	030	9	2	1.0	190	2	1.0	6.2
2006	11	06	18	6.9	115.4	240	2						0.0
2006	11	07	06	7.2	115.6	250	6	1	0.5	360	4	0.5	1.6
2006	11	08	18	7.3	118.6	100	15						0.0
2006	11	11	06	7.5	116.6	270	10	2	0.5	210	5	1.0	6.2
2006	11	12	18	7.2	115.5	040	7						0.0
2006	11	14	00	7.3	115.6	110	14	3	1.5	110	3	1.5	14.1
2006	11	20	00	6.9	115.0	110	15	4	1.0	030	2	0.5	25.0
2006	11	24	00	6.7	115.2	050	14	2	0.5	080	2	1.5	6.2
2006	11	26	00	7.5	115.8	070		2	0.5	080	3	1.0	6.2
2006	11	27	00	6.4	115.0	060	16	3	0.5	060	4	0.5	14.1
2006	11	29	18	7.1	115.4	040	14						0.0

2006	12	01	12	6.4	115.1	040		2	0.5				6.2
2006	12	02	00	7.0	115.6	320	9	3	1.0	030	3	1.0	14.1
2006	12	12	00	7.3	115.7	060	16	3	1.0	030	6	1.5	14.1
2006	12	13	12	7.1	115.6	210	4						0.0
2006	12	13	18	7.1	115.4	050	10						0.0
2006	12	14	00	6.6	115.3	040	12	2	0.5	050	5	1.5	6.2
2006	12	14	00	7.1	115.5	070	6		0.5	010		0.5	0.0
2006	12	15	12	6.9	115.5	040	16						0.0
2006	12	15	18	6.9	115.7	070	20						0.0
2006	12	17	00	7.4	116.4	080	15	4	1.0	030	5	1.5	25.0
2006	12	17	18	6.7	119.3	050	10						0.0
2006	12	19	00	7.3	115.7	100	7	5	2.5	090	6	2.5	39.0
2006	12	21	18	6.5	115.1	010	18						0.0
2006	12	22	12	6.7	115.2	150	7	2	1.5	340	3	1.5	6.2
2006	12	23	12	5.3	117.3	000	0	0	0.0	000			0.0
2006	12	26	00	7.3	115.7	070	13	1		010	5	1.0	1.6
2006	12	27	06	7.1	115.2	050	19	3	1.5	350	3	1.5	14.1
2006	12	28	18	6.5	115.2	030						0.5	0.0
2006	12	30	06	6.3	118.8	020		3	0.5	020	8	2.0	14.1
2006	12	30	18	6.6	115.2	070	18						0

Jabatan Meteorologi Malaysia

Sarawak Water

Period : 2006

Range :

Latitude - 1.5 to 4.5 N

Longitude -109.0 to 114.33 E

Year	Month	Day	ObsTime (UTC)	Latitude (degree)	Longitude (degree)	Wind Direction (degree)	Wind Speed (knots)	Wave Period (sec)	Wave Height (metre)	Primary Swell Direction (degree)	Primary Swell Period (sec)	Primary Swell Height (metre)	Wave Length (meter)
2006	01	05	00	3.2	112.6	140	10	3	1.5	010	3	1.0	14.1
2006	01	06	18	4.1	111.4	250	9	3	0.5				14.1
2006	01	07	00	3.5	109.9	070	5	2	0.5	350	7	1.5	6.2
2006	01	10	06	4.4	113.3	060	14			010	4	2.0	0.0
2006	01	10	06	4.4	113.3	060				010	4	2.0	0.0
2006	01	18	00	3.7	110.3	310	8	2	0.5	310	4	0.5	6.2
2006	01	26	00	4.3	113.1	160	11	2	0.5	340	3	1.0	6.2
2006	01	26	00	4.3	113.1	160	11	2	0.5	340	3	1.0	6.2
2006	01	26	12	4.4	109.9	340	8	3	0.5	330		2.0	14.1
2006	01	26	18	3.6	109.9	330	5	1	0.5	320	6	1.0	1.6
2006	01	30	00	4.4	113.2	250	4			360	2	1.0	0.0
2006	01	30	00	4.4	113.2	250	8			360	2	1.0	0.0
2006	02	02	00	3.6	110.0	020	15	2	0.5	050	8	2.0	6.2
2006	02	02	06	4.3	112.0	060	11	3	0.5	050	8	2.5	14.1
2006	02	04	00	3.2	112.6	020	13	3	1.0	030	3	1.0	14.1
2006	02	05	00	3.2	112.6	020	8	4	1.5	010	4	1.5	25.0
2006	02	11	18	4.3	111.9	040	10	3	0.5				14.1
2006	02	12	00	3.7	110.2	010	6	2	0.5	040	6	2.5	6.2
2006	02	25	00	4.1	113.0	040		2	0.5	060	3	0.5	6.2
2006	02	27	00	4.3	113.1	050	6			240	2	0.5	0.0
2006	02	27	00	4.3	113.1	050	12			340	2	0.5	0.0
2006	02	28	12	3.8	110.8	060	9	3	1.0	080	4	1.5	14.1
2006	03	03	00	3.2	112.6	040	16	3	2.0	020	3	2.0	14.1
2006	03	04	00	3.2	112.6	020	10	2	1.5	020	3	1.5	6.2
2006	03	05	00	3.2	112.6	030	11	2	1.0	040	2	1.0	6.2
2006	03	06	00	3.2	112.6	060	9	3	1.5	030	2	1.0	14.1
2006	03	09	18	3.4	109.3	030	4	2	0.5	040	3	1.0	6.2
2006	03	10	00	3.9	110.7	350	1	1	0.5	020	6	2.0	1.6
2006	03	10	00	4.5	112.2	040	13	2	0.5	190	2	0.5	6.2
2006	03	10	06	4.4	112.4	360	3	2	0.5	020	4	1.5	6.2
2006	03	15	18	4.5	113.3	080	12						0.0
2006	03	15	18	4.5	113.3	080	12						0.0
2006	03	16	00	3.3	112.5	160	9	2	1.5	050	3	1.5	6.2
2006	03	16	06	4.1	109.6	140	8	2	0.5	020	3	1.0	6.2
2006	03	17	00	3.2	112.6	030	9	3	2.0	010	3	2.0	14.1
2006	03	19	00	3.2	112.6	140	16	2	1.0	100	2	1.0	6.2
2006	03	19	00	4.1	109.2	080	16	1	0.5				1.6

2006	03	19	06	4.1	111.4	090	6	3	0.5	100	6	1.5	14.1
2006	03	19	12	3.5	109.8	100	2	2	0.5	140	4	1.0	6.2
2006	03	25	00	3.8	112.3	090	10	2	1.0	230	2	1.0	6.2
2006	03	30	00	4.2	113.1	190	19	2	1.0	140	2	1.0	6.2
2006	03	30	00	4.2	113.1	190		2	1.0	140	2	1.0	6.2
2006	04	01	00	4.3	113.2	130	15	1	0.5	190	2	0.5	1.6
2006	04	05	06	3.3	109.0	060	8	4	0.5	090	4	0.5	25.0
2006	04	13	12	3.4	109.3	090	8	2	0.5	060	3	0.5	6.2
2006	04	13	18	3.9	111.0	130	4	2	0.5	090	4	1.0	6.2
2006	04	14	00	4.5	112.6	100	3	1	0.5	030	2	1.0	1.6
2006	04	14	06	4.5	112.6	190	4	0	0.0	270	4	1.0	0.0
2006	04	15	00	3.6	112.9	180	10			010			0.0
2006	04	15	00	3.6	112.9	180	10			010			0.0
2006	04	15	12	3.3	112.9	290	9						0.0
2006	04	16	00	3.3	112.9	350	3	2	0.5	030	5	0.5	6.2
2006	04	16	00	3.3	112.9	350	23	2	0.5	030	5	0.5	6.2
2006	04	17	00	3.3	112.9	140	9	0	0.0	340	1	0.5	0.0
2006	04	17	00	3.3	112.9	010	11						0.0
2006	04	17	00	3.9	112.4	110	10	3	1.0	120	3	1.0	14.1
2006	04	17	12	3.3	112.9	010	11						0.0
2006	04	18	00	3.3	112.9	120	11	0	0.0	030	3	0.5	0.0
2006	04	18	00	3.3	112.9	120	11	0	0.0	030	3	0.5	0.0
2006	04	18	12	3.3	112.9	360	10						0.0
2006	04	19	00	3.3	112.9	200	1			350	6	0.5	0.0
2006	04	19	00	3.3	112.9	200	21			350	6	0.5	0.0
2006	04	19	12	3.3	112.9	090	5						0.0
2006	04	20	00	3.3	112.9	030	2	2	0.5	040	5	0.5	6.2
2006	04	20	00	3.3	112.9	030		2	0.5	040	5	0.5	6.2
2006	04	20	12	3.3	112.9	020	12						0.0
2006	04	21	00	3.3	112.9	150	15			020			0.0
2006	04	21	00	3.3	112.9	150							0.0
2006	04	22	12	4.5	112.7	250	3	2	0.5				6.2
2006	04	22	18	3.9	111.0	280	9	3	0.5				14.1
2006	04	23	00	3.5	109.5	090	1	0	0.0	040	5	0.5	0.0
2006	04	28	18	4.3	113.1	140	9						0.0
2006	04	28	18	4.3	113.1	140	9						0.0
2006	04	30	06	4.2	113.0	250	14						0.0
2006	05	04	00	3.9	112.5	180	10	3	1.0	180	3	1.0	14.1
2006	05	05	00	4.3	113.1	270	4			080	2	0.5	0.0
2006	05	06	06	4.0	112.9	030	2	0	0.0	050			0.0
2006	05	07	18	3.3	113.0	160	9						0.0

2006	05	08	00	3.3	113.0	140	10	2	1.0	270	2	1.0	6.2
2006	05	08	12	3.3	113.0	340	6						0.0
2006	05	09	00	3.3	113.0	010	16	3	2.0				14.1
2006	05	10	00	3.3	113.0	360	8	1	1.0				1.6
2006	05	10	06	3.3	113.0	340	6	3	0.5	020	2	0.5	14.1
2006	05	10	12	3.3	113.0	350	14						0.0
2006	05	11	00	3.3	113.0	140	12	2	1.0	350	3	1.0	6.2
2006	05	11	18	3.3	113.0	150	8						0.0
2006	05	12	00	3.3	109.1	060	5						0.0
2006	05	12	06	3.3	113.0	260	9	2	0.5	250	2	0.5	6.2
2006	05	13	06	3.3	113.0	270	10	2	0.5	250	2	0.5	6.2
2006	05	13	18	3.3	113.0	280	11						0.0
2006	05	14	00	3.3	113.0	190	7	2	1.0	220	2	1.0	6.2
2006	05	14	18	4.3	113.2	210	17						0.0
2006	05	14	18	4.3	113.2	210	17						0.0
2006	05	15	00	3.3	113.0	170	19	2	1.0	350	2	1.0	6.2
2006	05	15	12	3.3	113.0	230	5						0.0
2006	05	16	00	3.3	113.0	190	4	2	1.0	090	3	1.0	6.2
2006	05	16	12	3.3	113.0	330	5						0.0
2006	05	17	00	3.3	113.0	140	8	2	1.5	270	2	1.0	6.2
2006	05	18	12	3.5	109.7	190	2	1	0.5	020	5	0.5	1.6
2006	05	18	12	3.7	110.6	290	6	3	0.5	310	4	1.5	14.1
2006	05	18	18	4.1	111.5	040	7	1	0.5	020	5	1.0	1.6
2006	05	19	12	3.3	113.0	360	10						0.0
2006	05	23	00	3.5	112.9	170	10	1	1.0	330	2	1.5	1.6
2006	05	24	00	4.5	111.3	030	16	1	0.5				1.6
2006	05	25	06	4.4	109.5	070	10	2					6.2
2006	05	25	18	3.5	112.9	160	7						0.0
2006	05	26	00	3.5	112.9	170	9	1	0.5	320	2	0.5	1.6
2006	05	26	06	3.5	112.9	360	4	1	0.5	350	1	0.5	1.6
2006	05	26	12	4.0	111.2	100	7	2	0.5	170	5	1.0	6.2
2006	05	26	18	3.5	109.7	250	8	2	0.5				6.2
2006	05	28	18	3.5	112.9	100	3	2	0.5				6.2
2006	05	29	00	3.5	112.9	170	9	1	0.5				1.6
2006	05	29	06	3.5	112.9	270	11	2	0.5	090	2	0.5	6.2
2006	05	29	12	3.5	112.9	270	7						0.0
2006	05	29	18	3.5	112.9	160	5						0.0
2006	05	30	00	3.5	112.9	090	5	2	1.0	320	2	1.0	6.2
2006	05	30	06	3.5	112.9	250	6	2	0.5	200	1	0.5	6.2
2006	05	30	12	3.5	112.9	320	10						0.0
2006	05	31	00	3.5	112.9	350	8	1	0.5	340	1	0.5	1.6

2006	05	31	06	3.5	112.9	080	8	3	1.0	090	1	0.5	14.1
2006	05	31	12	3.5	112.9	130	12						0.0
2006	05	31	18	3.5	112.9	180	8						0.0
2006	06	01	00	3.5	112.9	130	7	1	0.5	340	1	0.5	1.6
2006	06	01	06	3.5	112.9	250	5	1	0.5	270	1	0.5	1.6
2006	06	01	12	3.5	112.9	310	6						0.0
2006	06	01	18	3.5	112.9	360	5						0.0
2006	06	02	00	3.4	113.0	140	7	1	0.5	030	2	0.5	1.6
2006	06	02	06	3.4	113.0	260	7	1	0.5	200	1	0.5	1.6
2006	06	02	12	3.4	113.0	330	6						0.0
2006	06	03	06	3.4	113.0	130	7	2	0.5	160	1	0.5	6.2
2006	06	03	06	4.0	112.9	260	8	0	0.0	350			0.0
2006	06	03	06	4.0	112.9	260	8	0	0.0	350			0.0
2006	06	04	06	3.4	113.0	020	1	0	0.0	310			0.0
2006	06	04	12	3.4	113.0	010	10						0.0
2006	06	04	18	3.4	113.0	160	6	1	0.5	110	1	0.5	1.6
2006	06	05	00	3.4	113.0	340	7	1	0.5	320	1	0.5	1.6
2006	06	05	06	3.4	113.0	290	5	1	0.5	260	1	0.5	1.6
2006	06	05	12	3.4	113.0	320	12						0.0
2006	06	05	18	3.4	113.0	360	8						0.0
2006	06	06	00	3.4	113.0	120	10	3	1.0	330	3	1.0	14.1
2006	06	06	06	4.4	113.0	240	5	2	0.5	250	3	1.0	6.2
2006	06	06	12	3.8	111.5	250	4	2	0.5	130	2	0.5	6.2
2006	06	06	18	3.4	113.0	360	5	1	0.5	010	2	0.5	1.6
2006	06	06	18	3.5	110.1	310	4	2	0.5	130	2	0.5	6.2
2006	06	07	00	3.4	112.9	190	10	1	0.5	010	2	1.0	1.6
2006	06	07	06	3.4	112.9	290	5	1	0.5	310	2	1.0	1.6
2006	06	07	12	3.4	112.9	310	12						0.0
2006	06	07	18	3.4	112.9	180	8						0.0
2006	06	08	00	3.4	112.9	170	10	2	1.0	020	2	1.0	6.2
2006	06	08	06	3.4	112.9	260	13	3	1.5	260	3	1.5	14.1
2006	06	08	18	3.4	112.9	130	6						0.0
2006	06	09	00	3.4	112.9	130	7	1	0.5	060	3	1.0	1.6
2006	06	09	06	3.4	112.9	340	8	1	0.5	100	2	1.0	1.6
2006	06	09	12	3.4	112.9	210	13						0.0
2006	06	11	18	3.6	112.5	210	13						0.0
2006	06	12	00	3.5	109.5	180	9	3	1.0	210	4	1.5	14.1
2006	06	20	18	3.8	110.6	260	3						0.0
2006	06	21	00	3.2	109.0	220	13						0.0
2006	06	22	00	3.8	110.5	250	5	2	0.5	270	3	1.0	6.2
2006	06	22	06	4.0	111.2	200	12	3	0.5	240	4	1.0	14.1

2006	06	26	12	4.5	113.4	200	9						0.0
2006	06	27	06	3.2	112.6	180	8						0.0
2006	06	27	06	3.3	112.9	180	8						0.0
2006	06	27	12	3.4	112.9	310	4						0.0
2006	07	01	12	4.5	112.9	340	11	3	1.0	310	5	1.5	14.1
2006	07	01	18	4.1	111.3	270	13	2	0.5	300	4	1.0	6.2
2006	07	02	00	3.4	109.6	200	9	2	0.5	230	5	1.0	6.2
2006	07	11	18	3.3	110.9	190	10	0	0.0				0.0
2006	07	12	00	3.8	111.9	180	9	0	0.0				0.0
2006	07	12	06	3.2	109.1	220	20	6	1.5	220	10	2.0	56.2
2006	07	15	06	3.3	112.9	270	5	0	0.0				0.0
2006	07	16	12	3.3	112.9			0	0.0				0.0
2006	07	16	18	3.3	110.9	230	9	0	0.0				0.0
2006	07	16	18	3.7	110.4	360	2						0.0
2006	07	17	00	2.8	109.9	230	9	0	0.0				0.0
2006	07	17	00	4.3	112.2	360	2						0.0
2006	07	25	18	3.7	110.3	030	9						0.0
2006	07	26	00	2.4	109.0	120	9	0	0.0				0.0
2006	07	26	06	3.3	110.9	140	9	0	0.0				0.0
2006	07	26	12	3.8	111.9	230	9	0	0.0				0.0
2006	07	27	00	4.4	113.3	230	10	2	1.0	340	2	1.0	6.2
2006	07	28	00	3.6	113.1	200	10	0	0.0	140	5		0.0
2006	07	28	12	3.4	112.9	300	3	1	0.5	210			1.6
2006	07	31	12	4.4	113.4	180	9	0	0.0				0.0
2006	08	02	12	3.8	112.0	130	9	0	0.0				0.0
2006	08	02	18	2.9	110.0	180	9	0	0.0				0.0
2006	08	03	00	2.4	109.0	180	9	0	0.0				0.0
2006	08	08	18	2.5	109.3								0.0
2006	08	09	18	3.4	112.9	140	9						0.0
2006	08	11	06	4.1	112.1	220	12	4	2.5	220	6	3.5	25.0
2006	08	12	18	3.8	110.5	200	7	2	0.5	210	2	0.5	6.2
2006	08	13	00	4.3	112.5	210		3	0.5	210	2	0.5	14.1
2006	08	14	12	3.3	112.9	290	5						0.0
2006	08	15	12	3.3	112.9	300	5						0.0
2006	08	16	00	3.3	112.9	080	10	2	1.0	310	2	1.0	6.2
2006	08	21	06	3.8	110.4	000	0			270	2	0.5	0.0
2006	08	22	00	4.3	112.2	220	9	1	0.5	150	3	1.0	1.6
2006	08	30	00	3.4	109.3	250	16	4	0.5				25.0
2006	08	30	12	4.2	111.8	150	16						0.0
2006	09	02	12	4.2	110.1	120							0.0
2006	09	06	12	4.4	112.6		2						0.0