ABDUL MUNIR HAFIZY LADONI

The Sources of Pollution in the Likas and Inanam River Basin in Kota Kinabalu, Sabah, Malaysia

ABSTRAK

Dasar pembangunan di Malaysia telah memberi kesan kepada perubahan sosial dan persekitaran yang pantas di Kota Kinabalu, Sabah. Jumlah penduduk yang meningkat secara berterusan, penerokaan daerah untuk kilang-kilang dan pembangunan infrastruktur lainnya telah memberi tekanan kepada alam sekitar. Perubahan yang begitu cepat terhadap pembangunan di bandaraya Kota Kinabalu juga telah memberikan kesan dan tekanan kepada lembangan di sungai Inanam dan Likas. Kualiti air di kedua-dua sungai ini sebanyak sedikit mengalami penurunan dan pencemaran. Demikian juga dengan luas tanah atau wilayah untuk pertanian sawah padi mengalami pengurangan. Lantaran itu diperlukan sesebuah kaedah dan teknik penderiaan yang jitu mengikut perspektif disiplin Geografi bagi mengenal pasti wilayah dan persekitaran yang berubah tersebut. Dalam kajian ini, Remote Sensing dan Sistem Maklumat Geografi telah digunakan untuk mengenalpasti jenis guna tanah dan kaitannya dengan kualiti air di kawasan tersebut. Kaedah konvensional untuk pengurusan lembangan, sama ada in-situ mahupun makmal, sangat mahal dari segi kos dan masa berbanding dengan penggunaan data Remote Sensing dan Sistem Maklumat Geografi. Satelit Remote Sensing mempunyai keupayaan dan kelebihan tersendiri, kerana ia boleh menyediakan data yang berulangan dari segi masa, murah dan liputan yang sangat luas. Dengan membangunkan data Remote Sensing sebagai sumber kajian, ianya juga mempunyai potensi yang cukup besar untuk memperolehi beberapa parameter air. Akhir sekali, ia dapat mengeluarkan hasil data baru melalui teknik Klasifikasi Tidak Terselia dan Klasifikasi Terselia untuk melihat dan menghasilkan peta guna tanah dan sumber-sumber pencemaran air di sungai Inanam dan Likas.

Kata-kata kunci: *dasar pembangunan Malaysia, perubahan alam sekitar dan lembangan sungai Inanam dan Likas, serta Remote Sensing dan Sistem Maklumat Geografi.*

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INTRODUCTION

Rivers and the surrounding land drained by them (catchments) support very important wildlife habitats. The water itself provides the environment for fish, plants and animals, while the banks and nearby land support creatures such as otters, kingfishers and dragonflies, and a variety of water-loving plants. Healthy populations of fish and mussels are widely recognized as a sign of a healthy river. These animals, which spend their entire lives immersed in water, cannot easily escape the pollution that enters their environment. Over the past quarter-century, beginning with the landmark Environmental Act 1974, the state government of Malaysia has made great strides in its efforts to reduce some of the most damaging pollutants from waterways. Although much work remains to be done, many rivers are now cleaner and healthier than they have been for decades. Unfortunately, little progress had been made in addressing "the most ubiquitous and serious threats to aquatic life". This seemingly benign substance essentially soil washed into streams is driving rare species to extinction, destroying fish populations and degrading aquatic ecosystems throughout the river.

Contamination of the aquatic environment due to human activities by direct or indirect actions resulting in the introduction of substances or energy into the environment may cause such deleterious effects as harm to living resources, hindrance to aquatic activities for example fishing, impairment of the quality of water and the reduction of amenities (Muler-Karger, 1992).

Such an effort can be done easily with using Remote Sensing Data and Geographic Information System with ground checking. According to Black *et al*. (1996), recent advances in computing and information technologies have made it possible to provide database systems that can dramatically improve the availability and monitoring system of the environment with relevant information to resource managers and communities (as cited by Ladoni, 2007). Environmental modeling for larger area and more difficult terrain has often utilized some form of remotely sensed data. Satellite images that capture not only the visible but also the invisible characteristics of an environment have greatly enhanced an analyst's ability to model the environment. Studies on various digital image processing techniques and combination possibilities with GIS (Geographic Information System) have been strong component in current modeling of the environment.

OBJECTIVES AND STUDY AREA

In essence, this research project involves connecting hydraulic modeling and GIS. The primary research objectives are: (1) to develop a true long-term sustainable river basin management plan; (2) to identify the relationship between land development and the river water quality; and (3) to identify the source of river pollution by using Geographic Information System and Remote Sensing.

The Inanam river and the Likas river, located in Kota Kinabalu, Sabah, Malaysia were selected as the study area for this project. Those river systems are an urban stream that flows south westerly through the Inanam, Likas and certain part of Penampang and Kota Kinabalu. Due to its proximity to numerous school buildings, homes and businesses, the location of the rivers is of great interest to city planners, developers and property owners. The area is situated within longitudes 137 30 03.88 E and latitudes 13 07 34.17 N, and longitudes 137 35 07.62 E and latitudes 13 02 15.58 N.

The 1991 census stated that the population of Kota Kinabalu is 209,175. Under a trend projection, it will grow to 481,054 by 2005. By then all the population is urbanised. The preferred strategy, however, is to decrease the urban population to 450,000 leaving approximately 31,054 people as rural. The following table shows a comparison between the trend and preferred strategy in 2005 together with the expected total urban land take and proportion of prime agricultural land.

Population	1991	Trend 2005	Preferred 2005
Total Population	207,175	481,054	481,054
Urban Population	160,184	481,054	450,000
Rural Population	48,991	0	31,054
Urban Development 1991-2005: 1,739 ha.		Of which 435 ha. **Prime Agricultural Land**	

Source: Department of Statistics Malaysia (1991).

The original topography of Kota Kinabalu varies from tidal swamps north of Kota Kinabalu town particularly around Likas Bay, Kolombong, Inanam, Yayasan Sabah area up to Menggatal, freshwater peat swamps and floodplains in the interior of Luyang, beaches along Tanjung Aru and Sembulan, some moderate to high hills in the northern part particularly Telipok and the coastal areas of Sepanggar Bay, Signal Hills, Kepayan Ridge and the Bukit Likas. Mountain ranges run parallel along the coast that forms the background for the Kota Kinabalu.

Industrial areas are mostly concentrated around Inanam township, Kolombong areas and along Jalan Tuaran (from Inanam) up to Menggatal. The new Kota Kinabalu Industrial Park (KKIP) at Sepanggar is set to be a major industrial area for Kota Kinabalu and Sabah. Light industry is another economic activity in Kota Kinabalu. Inanam and Kolombong are also established industrial areas. However, heavier industrial activities are being introduced with the opening up of the KKIP (Kota Kinabalu City Hall, 1999).

Agriculture area is about 35.6% of the Kota Kinabalu coastal zone area and river basin is suitable for agriculture. However, only 49.1% of that is being cultivated. It is found that cultivated land in the district exceeds the amount of land suitable for agriculture which indicates wide agricultural activities on unsuitable land. This is mostly found near Telipok

METHODOLOGICAL PROCESS: DATA COLLECTION & PREPARATION

As shown in figure 4.1., the study approach involves two levels incorporating the utilisation of Remote Sensing and Geographic Information System (GIS) techniques to analyse and produce the results from both methods in the study of the sources of pollution in the Likas and Inanam river basin. The summary is intended to describe the chronological process rather than to evaluate the substance of the methodology involved. In order to understand the overall methodologies involved, it is important to know the types of data used in this study.

These data generally are grouped into three main categories. They are: (1) landsat thematic mapper remotely sensed data; (2) in-situ data or field data; and (3) maps derived from geographic information system data. Each of these data sets contains information to be extracted and/or manipulated in the process of generating the thematic maps (Jensen, 1996).

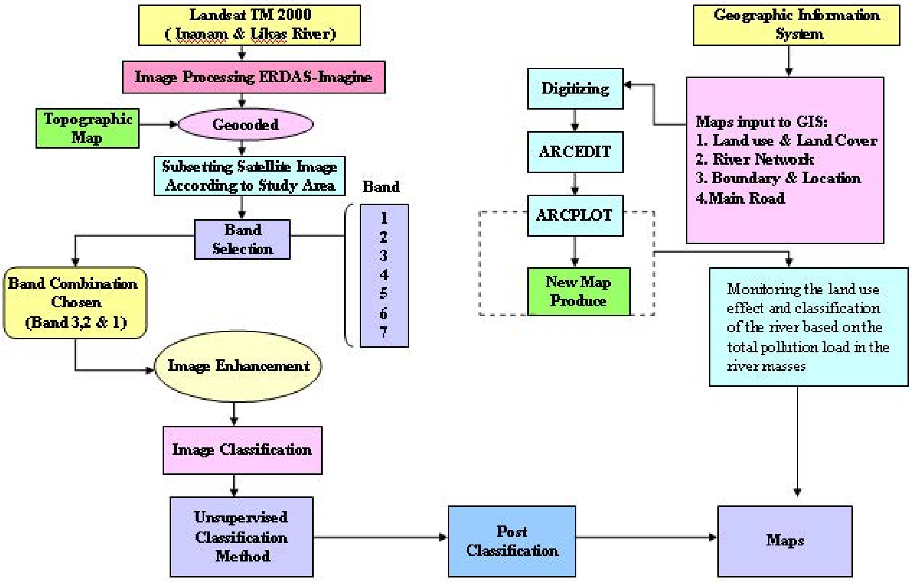

Figure 4.1.
Flowchart of the Digital Image Processing and Geographic Information System

A. SATELLITE DATA SET

The quickbird data were obtained from Malaysian Centre for Remote Sensing (MACRES) in Kuala Lumpur. Each scene was a 22303 pixel by 32516 pixel sub-scene of the original landsat image. The available satellite data is indicated in table 5.1.1. as follows:

Table 5.1.1.
The Available Satellite Data

SATELLITE NAME	DATE	SCENE SIZE
Quick Bird	12/2/2003	22303 X 32516

Figure 5.1.1 : Quick Bird Satellite Data , 2003

B. PRIMARY DATA SOURCES FOR GIS

Examples of some primary data sources for river classification using GIS are shown in table 5.2.1. The GIS application was carried out for mapping various thematic maps. The database was designed according to the objectives of this project, the main one being to detect, monitor and explain the parameters which influence the sediment concentration, especially for the river in the study area.

Table 5.2.1.
Sources of Map Input into the GIS System

TYPES OF INFORMATION	IDENTITY	SOURCES	SCALE
Landuse and Landcover Types(1997)	Present Landuse and Landcover	Agriculture Department	1: 100.000
River Network	Series T735	Dept. of Land & Survey	1 : 50 000
Boundary and Location	C-Type Edition	Dept. of Land & Survey	1 : 250 000
Catchment Points	Location by DOE	DOE	1 : 50 000

C. INPUT ATTRIBUTE DATA

This step is used to build the database before performing the analysis and creating the final products such as data and maps. It is the stage at which new information can be added to the database, for example, agricultural land use (descriptive data) or non-spatial data can be linked to the land use coverages. This attribute includes a code indicating the type of land use represented by each polygon (e.g. forest or agriculture) and the type of vegetation can identify. This step also provides the *joinitem* command to merge a data file with a feature attribute table to create an output file. In other words, when the value of the related item is the same in both tables, a record in the data file is matched to a record in the feature attribute table and both records are copied to the output file (table 5.3.1).

Table 5.3.1.
The Maps Prepared for GIS

Thematic Maps	Map Features	Attribute Data	Description
Landuse and Landcover	Polygon	Landuse and Landcover Types	Forest, Water bodies, Agriculture, Settlement, Bare land etc.
River Network	Line	Mains & Tributaries	Main, River Padas at Beaufort, Padas at Kemabong, Padas at Tenom, River Pengalan at Ansip, River Sook at Biah
Boundary	Polygon	Likas River Basin	State Boundary, International Boundary & Catchment Boundry.
Catchment Point	Polygon	Likas & Inanam & Tributaries	Likas River & Tributaries

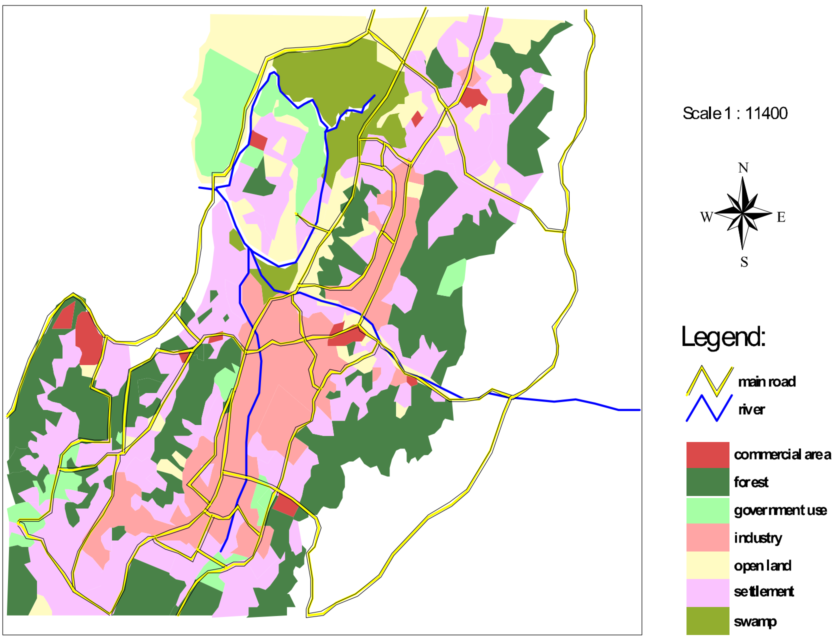

Figure 5.3.1.
(a) Land use and land cover in the study area

D. IN-SITU DATA

Remotely sensed data are being used in numerous fields and for a wide variety of applications. Consequently, the collection of in-situ data may take the form of field sampling, laboratory sampling or some combination of both. The techniques for these types of data collection ideally were learned from the physical and natural science courses most related to the specific field of study such as chemistry, biology, forestry, soil science, hydrology or meteorology. When in-situ data are to be used with remotely sensed data, it is important (for reasons explained elsewhere) that the position of these data is known in relation to the remotely sensed data. Due to the ease of use and increasing affordability, the Global Positioning System (GPS) is the ideal tool to be used to gather such positional data needed. Using a GPS receiver, the x, y and z coordinates can quickly be obtained to identify and locate individual samples in relation to remotely sensed data (Jensen, 1996).

E. THE SOURCES OF POLLUTION

Based on Malaysian Environmental Report, water pollution arises due to land clearing, earthworks, livestock farming and domestic waster and agro-based manufacturing industries (Department of Environment, 1994). In Malaysia industrial, sewage, agriculture and farm pollution account for 8%, 79% and

13% respectively of total pollution (Environmental Conservation Department, 1999). The greatest pollution problem in the rivers are the high load of suspended solids as a result of sediment pollution from poor soil conservation, runoff from logging, agricultural, plantation, mining and construction activities, and also from natural erosion. Recent findings at the Kinabatangan river estimated soil loss at 7.8 million tons per year. The Environmental Quality Report 1990, published by the Department of Environment, reported that 12 of the 17 or 65% of the rivers monitored in Sabah were heavily polluted with suspended solids which consisted of earth materials eroded from river channels and disturbed soil surfaces in the upstream areas (Department of Environment, 1994).

The Environmental Quality Report 1997 reported that 12 rivers in the State were polluted with NH3-N due to livestock farming and domestic waste in 1997. Six rivers were polluted with suspended solids due to mainly earthworks and land clearing activities. On BOD, there was no pollution reported in Sabah. The Environmental Quality Report 1998 reported that seven rivers in Sabah had been found to be polluted in terms of suspended solids, BOD and ammoniac nitrogen (as cited by Ladoni, 2007).

F. DOMESTIC SEWAGE

Municipal wastewater discharges, especially of untreated sewage, constitute an important source of pollution of inland waters in Sabah. Sewage poses a threat not only to human health but also increases the load of nutrients in the water, which use up oxygen as they decompose. The more oxygen is consumed, the more will aquatic life is impaired. In certain instances, conditions may become anaerobic, resulting in the mortality of aquatic life. Recent studies have found that the level of coliforms found in selected rivers estuaries and coasts of Sabah clearly indicated a high degree of sewage contamination along the river and coast of major towns in Sabah. These include Inanam, Moyog, Tawau, Sembulan and Likas rivers.

From the figures as shown not all sources of pollution are from the manufacturing industry, sources of pollution was identified by Department of Environment, domestic sewage predominate as potential sources of pollution. According to Mazlin *et al.*, the domestic waste generally high phosphate phosphorous load, is directly discharged into the river (as cited by Ladoni, 2007). The high load of phosphate-phosphorous poses a great treat to aquatic ecosystem, as their levels are higher than the threshold level for eutrophication. Most of the domestic sewage in the study area is come from settlement area as shown in figure 6.1.1. The riverside settlement was supply domestic sewage to river water. Squatter settlements are found on both side of the river such as in Pantai Teluk Likas, Kuala Likas, Kampong Gusung Likas, Kampong Muhibbah Likas, Kampung Cenderamata Likas, LPN Inanam, Kampong Nountun Likas and Kampong Garib Inanam.

Figure 6.1.1.
Riverside Settlement in the Study Area

G. RIVERSIDE SETTLEMENTS

Riverside settlement is a major activity that affected the river stream environment in term of pollution load. In the study area the riverside settlement can be divided into two categories: *first* is the housing, and *second* is the squatter. The development of economic in the last decade brought more land use changes. The riverside area are being developed, mitigation into the riverside area from rural areas and from neighboring countries has also increased with more and more of these people squatter on the riverside.

According to Kota Kinabalu City Hall (1999), there has 29 villages or area was determined as main location for squatter in 1999 compared with only 27 areas in 1997. The totals of squatter have been reported through the investigation are shown in table below:

Large number of population already migrated within the basin to avail the opportunity of job, housing and many other facilities. Rapid increase of population in the river basin increased the amount of pollutant. In the case of detergent use for laundry and other cleaning purposes ultimately reached to the

Table 6.2.1.
The Total of Squatter in the Kota Kinabalu City Hall Area in 1999

river systems with domestic waste effluent. The high load of domestic sewage was threatening aquatic environment. From figure 6.2.1. has shown the riverside settlement.

Figure 6.2.1.
The Squatter Along the Riverside

H. INDUSTRY

Kota Kinabalu is also the major business centre for the State of Sabah, Malaysia. Most of the economy is driven by private investment. New commercial development is expanding rapidly either in the town area or within the suburbs. Light and medium industry are another economic activity in Kota Kinabalu. Inanam and Kolombong area in the Likas and Inanam river basin were established as an industrial area for a long time ago. However, heavier industrial activities are being introduced with the opening up of the Kota Kinabalu Industrial Park (KKIP).

Figure 6.3.1.
Industrial Zone Located Close to the River

Industrial estates in the Likas and Inanam river basin are concentrated in the middle portion of the basin. All estates are located within easy reach of major highway and linking the major towns in and outside the basin. The Inanam and Likas area have lead to its rapid growth as a hub of industrial production in the Kota Kinabalu. Most industries are concentrated in and around the urban area such as Likas, Inanam, Penampang, Menggatal, Telipok and Tuaran.

The industries were operational in that area is multi-national companies, small industries and medium industries. Industrial development and activities contributed to water pollution, toxic and hazardous waste, soil erosion and degradation and impact to human health (Department of Veterinary Services and Animal Industry, 1999). Rapid industrial development in the study area had some impacts that are detrimental to its ecosystem. Some factories sited within industrial zones (figure 6.3.1) are located too close to Likas river and Inanam river, and having their effluent discharged directly in to the river systems (Kota Kinabalu City Hall, 1999).

Figure 6.4.1.
The Location of Oxidation Pond in the Study Area

It is generally known that water quality of the water in the Likas river and Inanam river had been gradually deteriorating. According to the Department of Environment's records, the rivers were classified as polluted. Records also show that a large number of the manufacturing facilities located along the both of the rivers are not equipped with effluent treatment facilities (Department of Environment, 1998).

I. OXIDATION POND

Two oxidation ponds are used for waste water treatment within the municipality. They are in Kampong Bangka-bangka near Yayasan Sabah, (longitude 137 31 23 E and latitude 13 06 03 N) and Taman Kinamount. The oxidation ponds are under the management of the KKCH (Kota Kinabalu City Hall) and the size of this area is covered by 100 acres. Regarding KKCH, the

Figure 6.5.1.
Chicken Hatchery Farm at Jalan Kiansom, Inanam

oxidation pond was created to fulfil and support 60,000 population effluent on the first phase and 100,000 population effluent in second phase. Most of the effluent after treatment process will drain out to the Buat river, Inanam river and Likas river eventually (Wong Chui Feun, 2003). Figure 6.4.1 shows the location of oxidation pond in the study area.

J. AGRICULTURAL

The list of livestock farms within the Kota Kinabalu municipality is presented in table below. It was obtained from DOVSAI (Department of Veterinary Services and Animal Industry) Kepayan branch. Kota Kinabalu City Hall (KKCH) is responsible to issue licences to the farm operators. However, at present, there are no law that states it is compulsory for the farm owners or operators to obtain a licence. Nevertheless, most of the big farms apply for a trading licence. Livestock farming is produced NH3-N and suspended solid to the river water. Sewage and animal waste are indicated by the presence of ammoniacal nitrogen.

Table 6.5.1.
The List of Livestock Farms in Kota Kinabalu District

Name of Farm Operator	Name of Farm	Location of Farm	No. of Livestock	Production of Eggs (per day)
CHICKEN HATCHERY FARM				
1. Teo Hin Cheong		Kg Keliangua, Menggatal	5,000	4,000
2. Tan Cheong Heong		Kg Keliangua, Menggatal	14,000	8,400
3. Sze Chi Ngai	Sze Chi Ngai Farm	Kg Kiambang Inanam	15,000	7,000
4. Kok Oh Leong		Bt 4 Jln Kiansom	12,000	9,000
5. Eng Vun Chuan	Menggatal Poultry Farm	Menggatal	40,000	24,000
6. Teo Hin Chong		Kg Keliangau	5,000	3,000
7. Wong Wah Peng	Eng Peng Farm	Kg Norowot Telipok	40,000	25,000

Name of Farm Operator	Name of Farm	Location of Farm	No. of Livestock	Production (chicken/cycle)
CHICKEN BROILER FARM				
1. Tan Cheong Heong		Kg Mansiang Menggatal	1,700	7,000
2. Chew Kim Chap	Susahil Pertanian Tuaran	Kg Giling Telipok	20,000	15,000

3. Yong Yun Chen		Kg Timbok Telipok	2,500	500
4. Pn Catherine Edward	KPD Project	Kg Kelingau Menggatal	3,060	3,000
5. Peter Thien		Kg Norowot Telipok	16,000	10,000
6. Pan Yun Lo	Ladang Kebuni	Kg Kebuni Inanam	50,000	20,000
7. Kung Lim	Kung Lim Farm	Kg Timbok Telipok	45,000	20,000
8. En Bius Siekul	KPD Project	Kg Keliangau Menggatal	6,000	6,000

Name of Farm Operator	Name of Farm	Location of Farm	No. of Livestock	Production (eggs/day)
DUCK HATCHERY FARM				
1. En Chai Kian Min	Multy Purpose	Kg Pulutan Menggatal	15,000	9,000

Name of Farm Operator	Name of Farm	Location of Farm	No. of 'Indung' (Female Pig)	No. of Piglets
PIG FARM				
1. Soon Tet Lee	Soon Farm	Kg Kitobu Inanam	40	300
2.	Eng Peng Farm	Kg Keliangau Menggatal	40	
3. Kour Nam Ngum	Consolidated Farm	Kg Timbok Telipok	200	2,600
4. Pan Yun Lo		Kg Kebuni	160	300
5. Yu Lim	Kung Lim Farm	Kg Timbok Telipok	140	1845
6.	Q.L. Farms Sdn. Bhd.	Kg Kayu Madang Telipok	229	2174
7. Pan Jun Lin		Jln Kiansam Inanam	8	25
8. Anthony Thien		Kg Norowot Telipok	200	2000
9.	Eng Peng Farm	Kg Norowot Telipok	100	1000

Source: DOVSAI (Department of Veterinary Services and Animal Industry), 1999.

RESULT AND DISCUSSION

The continuous economic and population growth in Sabah have led to the rapid land use development both in urban or rural areas. Since the sustainable yield of water in the Likas river and Inanam river depends on natural resources, it is extremely important to take precautionary measures of their loss to avoid any adverse impact on the environment. The chronology of land use and the impact on the water quality changes require the acquisition of the temporal satellite data set and in this regard, remote sensing and a geographic information system are expected to assist the detection of sources of pollution and supplied relevant information. Figure the next page shows the land use mapping using satellite image and Geographic Information System.

CONCLUSION

Due to the wide range of land use such as industrial factories, agriculture, plantations, urbanizations, building construction, road construction etc. In general, river water quality over the period of 1987-1993 had deteriorated at the rate of 1.19% per year. The seven year trend shows that, overall, 67 out of 87 river (77%) monitored had suffered the onslaught of increased pollutant loads from industrial and domestic effluents, silt, sewage and animal waste.Remote sensing data can be used for a great variety of practical applications, all of which relate to the environment.

The advantages of satellite remote sensing data are that one can obtain information from large areas both quickly and frequently. Study of river water mapping especially of sediment, chemicals, effluents and oil spills and many other problems are quite difficult to perform using conventional methods with field work. Satellite remote sensing and GIS is a better choice and can give very good performance to provide the kinds of data that satisfy one's requirements in terms of time, cost, synoptic coverage and immediacy.

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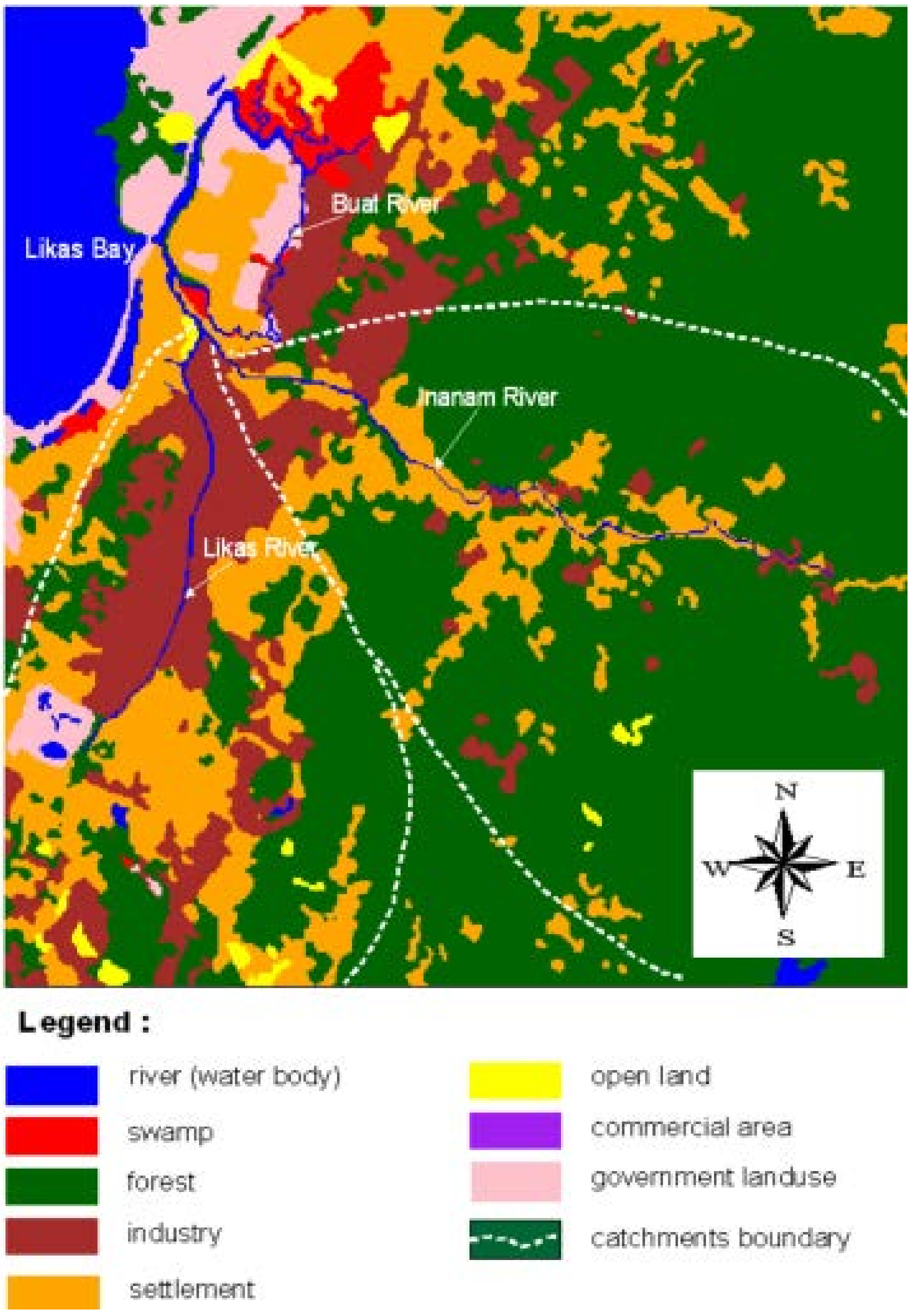

Figure 7.1.
Catchments Boundary of the Likas and Inanam River Basin
(Based on Satellite Image)

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