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A STUDY OF COASTAL AREAS IN MIRI, SARAWAK

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ABSTRACT
A study of Miri city's coastline (approximately 32km) is presented, covering coastal characteristics, coastal resources, water quality assessment, coastal pollution, coastal erosion and current coastal zone management. Physical and meteo marine conditions were studied to provide an overview of the city's coastal areas. Infrastructures and utilities built within the coastal areas such as ports are important non-natural resources which can enhance the socio economic growth of the city's coastal zone. Natural resources such as mangrove forests and coral reefs possess great ecological and environmental importance. Large amounts of pollutants originating from residential and commercial sources, and agricultural activities, are discharged into drains and streams before ending up in coastal water. Thus, samples of coastal water from several strategic locations were examined. Dominant pollutants found along coastal areas such as sewage, wastewater, oil and grease, solid wastes, agricultural loads and suspended solids were studied and identified. Erosion occurs along the coastline at different rates depending on the type of development implemented. It is suggested that sustainable protection approaches such as beach nourishment should be built instead of traditional methods of rock revetments and concrete blocks. Coastal zone management plans were implemented along the city's coastal areas, such as the Integrated Coastal Zone Management (ICZM) Miri – Suai pilot project, which was implemented a decade ago but was halted. Currently, the Integrated Shoreline Management Plan is being launched to produce a plan to manage the shoreline of the city.

Keywords: *coastal areas, coastal erosion, coastal pollution, coastal management*

INTRODUCTION
An estimated 50% of the world's population is residing within coastal areas. This figure could grow to 75% by 2020 [1]. Activities being performed along the coastal areas had transformed dramatically in the last two centuries, from agricultural and fishing industries to modern industries such as factories, oil and refinery plants and ports. The coastal area is the area where the ocean and land intersect each other inclusive of both the portion of the land and the portion of the contacted ocean. Alternatively, the coastal area is referred to as the zone limit where the land is affected by the sea and the sea affected by the corresponding land [2]. The extent of this intersecting zone may differ from country to country. In Malaysia, the coastal land area amounts to nearly 4.4 million hectares [3]. Sarawak alone possesses 2.24 million hectares or 51% of the country's entire coastal land areas. The coastline length in Sarawak is 1035 kilometres, with 80% of its population residing along the coastal zones [4], including Miri city. Miri is the second largest city in the state of Sarawak located at the northern region of the state. The city itself is established next to the coastline facing the South China Sea. Generally, the coastal area in Miri is gently sloped and sandy based especially in the city centre and south part. In this paper, a study of Miri city's coastline (approximately 32km) is presented, covering coastal characteristics, coastal resources, water quality assessment, coastal pollution, coastal erosion and current coastal zone management in Miri.

Coastal Characteristics

Physical Characteristics
The city of Miri is situated on the northern region of Sarawak, a state in East Malaysia. Sarawak is the largest state in Malaysia. The city is located at the latitude of 04''21'N and longitude of 113''55'. The majority of Miri city's coastline is classified as the open coastline type, except two areas, which are the Miri and Baram River mouths. A coastal bay is formed along the coastline ranging from the Baram

River mouth till Tanjong Lobang in the south. The entire city's coastline is bordered by the South China Sea.

Meteo-Marine Conditions

The city's coastal meteo-marine characteristics are influenced heavily by the South China Sea. Local climate is of tropical humid climate all year long as the city is located close to the equator line. Two major monsoons dominate the city meteo-marine scenario, namely the North East and South West monsoons. The months of April and October are referred as the transition periods. Wave conditions along the state coastline facing the South China Sea are influenced by the waves generated by the monsoon winds. The tides surrounding the city coastal areas are affected heavily by the tide within the Pacific Ocean and occur due to astronomical tides of diurnal tides [5].

Population Demographic

As of 2008, an estimated population of 215 000 resides within the city and its coastal zones making it the second most populated city in the state [6]. A total of 24% of the city's population lives outside the city, scattered around its outskirt zones such as Baram. The ethnic population distribution among Miri's citizens is as shown in Figure 1. The Chinese, Iban and Malay races form the three largest ethnic races consisting of 78% of the city population [6]. The presence of a large number of foreigners (6.2%) is mainly due to the economic opportunities available in the city particularly within the oil and gas sector.

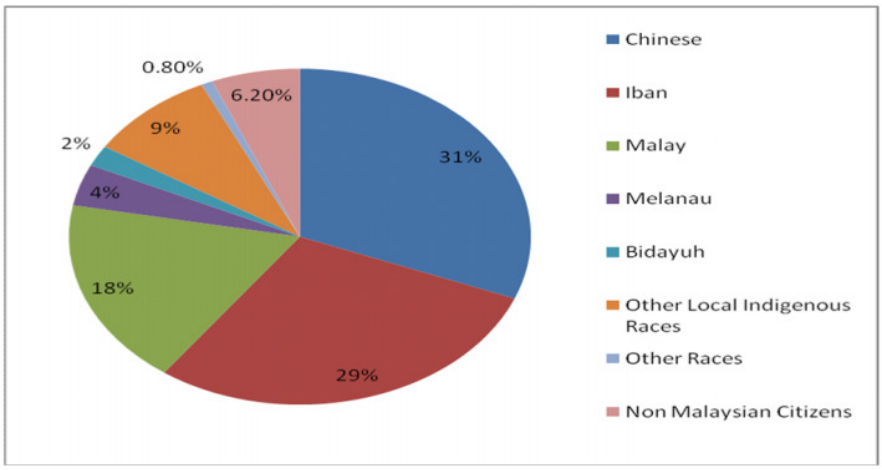

Figure 1.Distribution of ethnicity in the population of Miri city

Coastal Resources

Infrastructure and Utilities

Basic amenities such as water supply, electricity, healthcare, education and telecommunication are provided within the coastal areas. Extensive road networks and highways are built around the city and connect the city to other major cities through the Pan Borneo Highway. Miri Port which is located at Kuala Baram acts as a trading point for the entire northern region of Sarawak. Docks and jetties are scattered around the coastal areas especially along the banks of Miri River and Baram River in the areas of Krokop, Piasau and Baram. They serve as loading and unloading locations for goods such as fisheries products, oil barrels and timber products. An anchorage zone was built 6km northwest off the Miri river mouth.

Marine Ecology

Coral Reefs

A majority of the coral reefs are concentrated off the coast of Kuala Bakam, south of the city around the Sibuti area. Among the major reef in the coastal water zone include Kenyalang Reef, Scubasa's Reef (nearest to city centre), Tyre Reef, Grouper, Vhk Reef, Sunday Reef, Mike's Reef, Maru Reef (off Lutong coast) and Eve's Garden Reef [7] and [8]. Coral reefs serve as breeding locations and habitat for various reef fishes and marine invertebrates which are important food sources for higher level of marine fishes. A high level of sediments and suspended solids within coastal waters originating from

coastal areas and the inland is a major threat to coral reefs as they would accumulate on coral surfaces and suffocate the corals to death. Offshore drilling activities release excessive mud, producing the same impact on corals as sediments [9]. Other threats towards the coral reef population include harmful fishing methods such as fish bombing and cyanide fishing, toxic pollutants of nutrients, sewage and industrial waste. A total of 190 000 hectares of coastal water area containing various coral reefs was gazetted as a national park in 2007 located within the Subis Planning Zone located at the southern coastal water region of the city coastline [10].

Seagrass

In Miri, seagrass is thrives near shallow water coral reefs and shoals. They are normally found within the shallow estuarine zone with water depths not exceeding 10 meters [11]. The city's coastal water is rated as being highly productive, where more than 15 species of seagrass exist [12]. Similar to coral reefs, seagrass also form breeding grounds and habitat for various marine species, particularly during their juvenile phase, by providing shelter or protection before they move on to deeper coastal waters as they mature [13]. Marine species such as green turtles, dugongs, seahorses and seadragons make seagrass their main food source [11]. Together with coral reefs, seagrass forms a physical barrier beneath the surface of coastal waters and would disperse incoming sea waves [14]. Seagrass also has the ability to absorb nutrients from pollutants and sediments, thus providing natural assistance in cleansing coastal waters [11]. Heavy sediments offload and harmful chemical pollutants such as metal elements and grease will kill off seagrass by suffocation and contamination. Other threats to seagrass include harmful fishing methods, coastal land reclamation, dredging, and an increase in coastal water temperature.

Fish

There are an estimated 518 fish species, 35 crustacean species and 2 jellyfish species habituating the state's coastal waters bound by the Exclusive Economic Zone [15]. The most commonly found fish species along the city's coastal water is from the Mugllidae family [16]. *Penaues monodon,* or better known as "tiger prawn" among the locals, is widely available.

Fauna and Wildlife

As the majority of the city's coastline has been developed into commercial and residential areas, fauna in its coastal areas consist mainly of insects and birds. Exotic wildlife such as reptiles is rare across the developed coastal areas in the city, except around the mangroves and peat swamp forests near the Bakam, Baram and Senadin areas.

Terrestrial Vegetation

Beach Forest

Sandy beaches or sand pit areas covering nearly 70% of the city's coastline is commonly found from Kampung Nelayan Kuala Bakam (locally known as Hawaii Beach) in the south, to all the way to the Lutong beaches in the north. Dominant vegetation along the unstable section closest to the sandy beaches or the upper storey consist mainly of species such as *Ipomoea pes-caprae* and *Canavallia rosea*. Towards the inland areas where the soil condition and stability are better, shrubs and low trees found included *Hibiscus tiliaceus*, *Casuarina equisetifolia*, *Acacia auriculiformis* and *Cocos nucifera*. Vegetation in beach forests possess long roots penetrating deep into the soils providing them with strong strength and stability to withstand the incoming sea waves, thus reducing erosion impact [1].

Mangroves

Mangrove forests cover a total of 2278 hectares of coastal land in the Miri Division [17] dominating vegetation in the city, including the Baram (north) and Bakam (south) sections of the inland areas, approximately 100 meters from the sea water. Mangrove forests found at these areas mainly consists of the *Rhizophora* species group from the *Rhizophoraceae* family [18]. They are also known among the locals as Bakau. Mangrove forests are home to various exotic flora, avifauna and other fauna such as fishes, shellfish, prawns and crabs. Mangroves' roots are able to absorb pollutants such as nutrients, from water originating from the sea or rivers and streams, and could therefore act as a 'filter' to cleanse the surrounding water [17]. Other than nutrients, sediments from rivers or inland runoffs can also be trapped, thus reducing coastal water turbidity. The barriers of mangrove forests with their strong roots provide coastal protection from incoming natural forces such as turbulent sea waves or storms, and at the same time reduces shore erosion. Plans are underway to transform the Baram's mangrove forests into eco-tourism parks by the Natural Resources Environmental Board (NREB).

Peat Swamps
An estimated 320 000 hectares of peat swamp lie within the Miri division [19]. Within the coastal areas in the city, a huge portion of land north of the city particularly in the Senadin and Tudan areas consist of peat swamp. Peat swamps in these areas are reclaimed for land development and agricultural activities. Compared to other peat swamp forests particularly those from the inland, the peat swamps found within the city's coastal areas are less diversified in terms of species of flora. Peat swamps found here are categorized as mixed swamp forests consisting mainly of small trees and shrubs. Species dominating these areas include *Garcinia cuneifolia*, *Dactylocladus stenostachys* and *Dryobalanops* [1]. Peat swamps are advantageous in their abilities of recharging and discharging ground water, thus maintaining a high water table and good flowing condition. Peat swamps can also store and moderate water providing flood mitigation control [19]. Haze arising from the burning of peat swamps has long plagued the city's air quality particularly along the Baram, Senadin and Tudan areas. Burning of peat forests contribute to the highest amount of smoke compared to other forests, and at the same time would require vigorous efforts to diminish the fire on peat swamps as dried peat beneath the soil surface would catalyse the fire flames [19].

Fishery
The fishing industry within the city is not implemented at a large commercial scale and involves mainly traditional and medium sized commercial fisheries. Traditional fisheries are carried out largely by the Malays and Melanaus along coastline villages, utilizing simple equipment such as non-engine boats and nets [20]. As for commercial fisheries, larger vessels are used, generating more income for the fishermen. Total fish landing within the city in 2007 totalled 10072.5 tons [21]. Landing locations for the fishing vessels are mainly concentrated on the Miri Fishery Department jetty located at Krokop along the bank of Miri River. Several small jetties also exist along this river serving as landing locations owned by fishery product companies. Demersal fish, pelagic fish and shrimp are among the major fishing groups available within the inshore coastal water [15]. Among the major fish species (local names) captured include *Kerisi, Mengekrong, Temenggong, Selayang* and *Bilis* [21]. Coastal water bound from Bakam till Baram is rich in crustaceans or shrimp resources. Pollution, over-fishing, harmful fishing methods and the destruction of fish habitat remain as the major threats faced by the city coastal fishery resources, but the extent of these threats have not reached the critical stage for the time being [20].

Coastal Water Quality Assessment
In order to examine the levels of coastal water quality along the city's coastline, water sampling and testing were performed. For testing water quality parameters and fecal contamination (Table 1), the Hach self-contained test kits (Surface Waters, and Total Coliform and E Coli test kits) were used. The test kits are ideal for field testing industrial discharge in both ambient and environmental applications. The procedure for determining each parameter is conducted in accordance with the laboratory manual attached with test kit. The BOD_5 test is a common test to determine the pollutant load of water and wastewater. Here, the BOD test is conducted according to the Standard Method for the Examination of Water and Wastewater 5210: Biochemical Oxygen Demand. To determine BOD_5, the dilution method, which is a standard method of the American Public Health Association (APHA) and approved by the U.S. Environmental Protection Agency (UEPA), was used. Three coastal sampling locations were selected namely – Miri-Kuala Baram Highway shore (Location 1), Lutong Beach (Location 2) and Miri River's Mouth (Location 3) as shown in Figure 2.

Figure 2. Sampling Locations

The tested water quality parameters included temperature, pH, dissolved oxygen, ammonia nitrogen, total chlorine, nitrate, phosphorus, total suspended solids (TSS), biochemical oxygen demand (BOD_5) and fecal contamination. The results of the assessment for these three locations were tabulated in Table 1 below.

Table 1: Coastal Water Quality Assessment Results

Parameters	Units	Sampling Location		
		1	2	3
Temperature	ºC	27.5	26.0	26.5
pH	-	8.0	8.3	8.4
Dissolved Oxygen	mg/*l*	7.56	7.60	7.62
Ammonia Nitrogen	mg/*l*	0.10	0.10	0.10
Total Chlorine	mg/*l*	0.05	0.05	0.03
Nitrate	mg/*l*	7.92	17.60	8.80
Phosphorus	mg/*l*	0.20	0.73	0.63
Total Suspended Solids	mg/*l*	266.7	233.3	213.3
Biochemical Oxygen Demand	mg/*l*	1.45	2.02	1.11
E. Coli	MPN/100m*l*	5.2	2.2	5.2

Coastal water quality samples along the city coastline from the Miri River mouth till Baram River mouth at the time of the sample collection can be categorised under Class III of Interim National Water Quality Standards Malaysia (INWQS), which permits human body contact activities such as swimming and less sensitive aquatic fishes and moderately tolerant species to survive within the water system.

A low level of ammonia nitrogen, *E. coli*, BOD_5 and total chlorine were observed. Nutrients such as nitrate and phosphate, as well as total suspended solids showed medium levels of contamination. The high level of total suspended solids can be due to large amounts of surface runoff from coastal inland

zones such through the Lutong River and Baram River. The riverbanks of these two rivers are largely developed with residential and commercial properties which generate a large amount of runoff. Eroded soils and its sediments from land clearing for agricultural activities further inland also contribute large amounts of suspended solids. These suspended solids and sediments would be drained to streams, rivers and drains by rainwater before reaching coastal seawater. The high level of nitrate and phosphorus can also be attributed to industrial and domestic usages of detergent, agricultural fertilizers, pesticides and herbicides. These sediments and nutrients would be carried by rainfall into river streams before ending up in coastal water. The high dissolved oxygen and low BOD_5 level at these sampling locations is due to the open coastline which provide good flushing capability. Incoming waves dominating the coastline can disperse BOD, thus resulting in lower levels as tested and enabling the dissolved oxygen amount to be maintained at high level. As *E. coli* dies off quickly away from its origin, it can only be found in higher concentrations closer to their sources. The main source of *E. coli* comes from wastewater from squatters and animal stock farms located on the riverbanks, or stream flow which contains discharged domestic wastes, without adequate treatment. Overall, the good flushing capability at the sampling locations enables pollutants to be dispersed easily.

Coastal Pollution

Sewage and Wastewater
Major contributors of untreated wastewater come from the squatter colonies dominating Miri River's banks near the city centre, along the areas of Brighton Centre, Piasau, Krokop, Pujut and Lutong districts. There are no proper wastewater treatment faciilities at these colonies. Domestic waste is discharged directly into rivers and streams before reaching coastal waters. Within the Lutong shore, next to the Lutong Beach, there are approximately 80 squatter families currently in residence. Another 160 squatter families are settled at the Miri River banks from the Pujut area towards the river mouth of Brighton Centre [23]. Food restaurant outlets, hawkers and markets within the city and its surrounding areas such as city food markets, seafood restaurants and hawkers are producing significant amounts of untreated wastewater from their food-based activities, which flow into drains before reaching rivers and coastal waters.

Oil and Grease
Oil and gas drilled offshore would be channelled to oil and gas facilities located at Lutong before being processed or exported as crude oil and gas. Therefore, oil and grease contamination along the coastline is a frequent occurrence. The latest critical oil spillage to occur within the city coastal zone was in 2008 when a 13 kilometre oil pipeline connecting an offshore platform to the onshore Miri Crude Oil Terminal (MCOT) suffered leakage [24]. Shipping industries concentrating around Piasau (Miri River) and Kuala Baram (Baram River) also contribute towards oil and grease pollution of coastal waters. The cleaning of ships, particularly within their engine rooms, produces large amounts of oil and grease wastes. In addition, oil spills and disposal also come from fishing boats operating around the coastal waters. Beaches along the city indicate a serious level of tarball contamination particularly along the Lutong beach, which is located not far from the oil and gas facilities. Other beaches within the city such as Hawaii Beach and Luak Esplanade are also subject to tarball pollution.

Solid Wastes
With a population of close to 215 000, the city produces 130 tons of wastes daily, ranging from plastic products to metal wastes [25]. A total of 20% of these wastes constitute paper products while another 21% are synthetic products such as plastic and rubber. Plastic products are the waste being dumped at the city's landfills. Most of the wastes found along the coastline and coastal waters originate from onshore, disposed into drains and rivers and flowing into the open coastline before washing up ashore. The most severe solid waste pollution can be seen along the city centre's coastal zones, especially near the Miri River Mouth of Brighton Centre and along the beaches of Luak Esplanade and Hawaii. Squatter colonies along Miri River also dispose a large amount of solid wastes into the river.

Agricultural Load
Agricultural activities, especially palm oil plantations at the inland are utilizing large quantities of fertilizers, pesticides, herbicides and other chemicals to increase their agricultural yields. Rainwater and its runoff will bring these pollutants from the soil surface and subsurface to the nearby streams and rivers before ending up in the coastal waters. Palm oil plantations require high amounts of fertilizers,

pesticides and herbicides compared to other agricultural plantation activities. Palm oil mills on the other hand also produce effluents from their refinery plants. Treatment is required for these effluents but most of the palm oil mills in the region do not possess efficient treatment facilities. These effluents are normally disposed into rivers heading towards coastal waters. The high concentration of nutrients such as nitrate and phosphorus from these chemicals would trigger algae bloom (eutrophication), excessive growth of freshwater weeds (such as *eichhornia crassipes*) and red tide occurrence in coastal waters [5].

Soil Erosion

A large amount of sediments originate from rivers, such as Baram River, due to its large catchment area which provides large amounts of eroded sediments. Soil erosion occurs inland as a result of intensive and unsustainable land clearing activities such as logging and palm oil plantations. As of December 2008, the size of palm oil plantation areas within the state stood at 744 372 hectares, or nearly 6% of the total land size of the state [26]. It is expected that this number would grow to 1 million hectares by the end of 2010. Coupled with high rainfall all year long, this runoff would be carried into nearby rivers, reaching coastal water at the end. Clearing of steep land would produce higher rates of erosion due to higher runoff velocities [5]. Other than inland soil erosion, commercial and residential land development also increases the amount of urban sediments into coastal waters.

Coastal Erosion

Erosion occurs across the city coastline, and is a significant issue. However, erosion occurs with distinct rates due to each zone's development and geographic condition. With little islands and reef barriers in its coastal water area, the open coastline of Miri's shores is receiving undisturbed and powerful waves from the South China Sea. Combined with littoral drift particularly during the wet Northeast Monsoon, the rate of erosion along the shoreline is typically high. The dominant wave crest pattern along the city coastline is acting in the direction of 30 to 45 degrees to the shoreline. This aids the littoral drifting rate and has further driven the shores' sediment removal rate. Vegetation is also sparse along the city's shorelines except the presence of small bushes and minor beach forests. These continuous erosion activities have led to the formation of bay shorelines in the shape of the incoming wave crest pattern within the city from Kuala Baram till Tanjong Lobang. Based on the National Coastal Erosion Study in 1986 [27], coastal erosion risk levels can be categorized into three categories, taking into account existing coastal infrastructure and socio-economic aspects as follows:

- Category 1 – Erosion rates are critical causing high level threats to infrastructure and facilities along the shoreline and require immediate prevention actions.
- Category 2 – Erosion rates are at a moderate level with mild or low threats to infrastructure and facilities along the shoreline and require proper management plans to prevent further erosion damages.
- Category 3 – Erosion rates are at a low or non-existent level with virtually no threats to infrastructure and facilities along the shoreline and do not require any attention for the time being.

The erosion observation along several popular coastal locations around the city, and their erosion risk classification based on the National Coastal Erosion Study 1986 guide is tabulated in Table 2 below.

Table 2. Erosion condition and risk around coastal areas of Miri

Coastal Zone	Existing Environment	Erosion Risk Category
Kampung Nelayan Kuala Bakam (Hawaii Beach)	Fishing villages Residential and recreational areas	3
Luak Bay and Esplanade	Recreational area	2
Tanjong Lobang	Hotel and resort	2
Marriot Resort and Spa	Resort development	1
Marina Bay Resort	Villages and golf club	1
Kampung Pulau Melayu	Residential, squatters and recreational areas	3
Lutong Beaches		3
Miri – Kuala Baram Highway	Highway road	1
Kuala Baram	Industrial zones and port facilities	1

The coastal areas possessing the most critical erosion zones within the city include the Miri – Kuala Baram highway, the beach adjacent to the Marriot Resort and Spa, Marina Bay Resort, Miri River Mouth and Kuala Baram (River mouth). These areas are subject to direct exposure to coastal waves without any sufficient vegetation. Coastal protection works implemented are listed in Table 3 below.

Table 3: Coastal protection works around coastal areas of Miri [29]

Location	Coastal Defense Type	Year
Miri – Kuala Baram Road, KM 2	650m of rock revetment	1997
Marine Department Lighthouse, Kuala Baram	200m of rock revetment	1998
Miri – Kuala Baram Road, KM 9	374m of rock revetment	1999
Pantai Lutong, Miri – Kuala Baram Road	470m of rock revetment	2000
Miri – Kuala Baram Road, KM 20	1.5km of rock revetment	2001
Miri – Kuala Baram Road, Pan Borneo Highway	1.9km of rock revetment	2006
Marriot Resort and Spa	550m of rock revetment and 170m of concrete blocks	2007
Marina Bay Resort	Rock revetments and Beach nourishment	N.A.
Miri – Kuala Baram Road, Pan Borneo Highway Phase 2	800m of rock revetment	Ongoing process

Currently, all the coastal defences' works within the city's coastal zone consist mainly of rock revetments, groynes, seawalls, breakwaters and concrete blocks which are hard engineering methods. Apart from these defence works, it is suggested that planners and engineers look into various alternative solutions, especially the promising soft engineering solutions such as beach nourishment, artificial headlands, artificial reefs, sediment filled geotextile tubes and mangrove replanting.

Coastal Zone Management

Presently, the only coastal zone management program being applied within the city coastal areas is the Integrated Shoreline Management Plan (ISMP) of Miri. The previous coastal zone management approach performed was Integrated Coastal Zone Management or ICZM through Miri – Suai Pilot Project (MISPA).

MISPA

This project was launched in August, 1998 and covered a coastline stretch of 84km [27]. The project was implemented with support from the state government, and was funded by the Danish government involving all related stakeholders. The main purpose of this pilot project was to serve as a platform to obtain valuable lessons and data for future implementation of ICZM for state level. However, the project was halted due to lack of funding and participants' responses. No further details are available from 2001 onwards.

ISMP Miri

The status of the project is still within the preliminary drafting stage as it has just been launched at the time of writing. The study area includes the Brunei border up to the Bintulu border, covering a coastline length of approximately 130 kilometres [28]. Among the major aims outlined for the ISMP of Miri are to protect and reduce the exposure risks of coastal erosion and flooding, maintain the water quality of coastal zones and provide efficient and sustainable planning of coastal land usage.

CONCLUSIONS

Miri city's coastline consists of an open coastline, with two major river mouths (Baram River at its northern region and Miri River at its city centre). A bay is formed along the coastline ranging from the Baram river mouth till Tanjong Lobang in the south. Modern infrastructure and utilities, namely a port, highways, oil and gas processing plants as well as hotels are located within the city's coastal zones. These features must be upgraded from time to time as they are critical to the city's socioeconomic growth. The city's coastal zones are also blessed with diverse resources such as coral reefs, seagrasses and fishes, natural oil and gas and various terrestrial vegetation. Coastal water quality around the city's coastline was assessed, and can be categorized under Class III of Interim National Water Quality Standards for Malaysia (INWQS). However, high levels of total suspended solids were observed at all of the monitoring locations suggesting high sediment output from onshore areas and inland development activities that may not fully comply with the erosion control guidelines. Nitrate and

phosphate were quite high, especially for coastal areas near the industrial areas of Lutong and the Miri River Mouth. Other water quality parameters assessed such as pH, temperature, dissolved oxygen, biochemical oxygen demand, total chlorine and ammonia nitrogen show safe levels. Major pollutants found within the city's coastal zones include sewage and wastewaters, oil and grease, solid waste, agricultural pollutants, including nutrients and suspended solids. Several locations around the city coastline are experiencing critical erosion issues and require immediate and long term protection approaches. These areas include Miri – Kuala Baram highway, Marriot Resort and Spa, Marina Bay Resort, Miri River Mouth and Kuala Baram (River mouth). Instead of using the traditional rock revetments, groynes and concrete blocks, other promising soft engineering approaches such as proper setback limit for development, beach nourishment, artificial headlands and sediment filled geotextile tubes is suggested. For the time being, there is no coastal zone management policy or programs being implemented in the Miri city region, as well as the state of Sarawak. There are various challenges and issues within Miri city's coastal areas. For sustainable development, joint efforts from all stakeholders are required. Awareness must be raised among the public regarding coastal management and protection issues before any development or protection works are to be implemented.

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REFERENCES

[1] Mamit, J. D., and P. Sawal. (2001) Environmental Degradation of the Coastal Zone of Sarawak. In Integrated Coastal Zone Management. eds. Chew, D., P.Sawal, and A.H. Sim. (pp.37-46), The Sarawak Press Sdn. Bhd., Kuching.
[2] Haslett, S. K. (2009) Coastal System, Routledge, New York.
[3] Ghazali, N.H.M. 2006. Coastal Erosion and Reclamation in Malaysia. Aquatic Ecosystem Health & Management Vol 9, No. 2: 237-247. Informaworld. http://www.informaworld.com/smpp/title~content=t713393886 (accessed April 7, 2009).
[4] ICZM Unit Sarawak. 2000. http://www.did.sarawak.gov.my/www/iczm_main.html (accessed March 4, 2009).
[5] Danish Hydrology Institute (2005) Sabah Shoreline Management Plan Baseline Report – Regional Description. Kota Kinabalu.
[6] Department of Statistic Malaysia (2007) Monthly Statistical Bulletin Sarawak November 2007, Kuching.
[7] Sigan Daniel, R. (2000) Regional Conference on Integrated Coastal Zone Management, May 2-4, 2000: Local Participation in Coastal Zone Management: MISPA's Experience, Miri Resident's Office.
[8] Awang, D. (2004) Preliminary Study on the Coral Reef Resources at Luconia Shoals, Miri Sarawak. Fishery Research Institute, Vol 9. No.2. 6-7. http://www.fri.gov.my/friswak/publication/luconiafri.pdf (accessed July 25, 2009).
[9] McManus, J. W. 1988. Coral Reef's of the Asean Region: Status and Management. Ambio Vol 17, No.3: 189-193. JSTOR Archive. http://www.jstor.org/stable/4313452 (accessed April 3, 2009).
[10] Puvaneswary, S.. 2007. Sarawak's Underwater Treasures. http://www.ttgasia.com/index.php?option=com_content&task=view&id=13582 (accessed July 26, 2009).
[11] Choo, C.K. 2006. SOS Volunteer Handbook – Save our Seahorses First Edition. http://www.seagrasswatch.org/Methods/Manuals/SOS_volunteers_handout.pdf (accessed September 20, 2009).
[12] Seagrass Atlas Map. 2009. United Nations Environment Program – World Conservation Monitoring Centre. http://bure.unep-wcmc.org/imaps/marine/seagrass/Run.htm (accessed August 19, 2009).
[13] Danish Hydrology Institute (2005) Sabah Shoreline Management Plan Baseline Report – Regional Description. Kota Kinabalu.
[14] Tan, C. L. 2005. Integrated approach vital in designing marine protected areas. TheStar Online. http://thestar.com.my/lifestyle/story.asp?file=/2005/10/18/lifefocus/12263102&sec=lifefocus (accessed July 21, 2009).

[15] Rajali, H. and A. A. Aziz. 2008. Potential and constraints for offshore fishing in Sarawak. Workshop on assessment and management of offshore resources of South and Southeast Asia. Bangkok, Thailand. http://www.apfic.org/modules/xfsection/download.php?fileid=309 (accessed July 29, 2009).
[16] Centre for Technology Transfer and Consultancy UNIMAS (1995) Proposed Coastal Reclamation Works for Miri Resort City Project, Miri, Sarawak, EIA. Kuching: NREB Miri.
[17] Marajan, E. (2001) Mangrove Resource Management In Sarawak. In Integrated Coastal Zone Management. eds. Chew, D., P.Sawal, and A.H. Sim. 54-57. Kuching: The Sarawak Press Sdn. Bhd.
[18] Chemsain Consultant Sdn. Bhd. (2002) Proposed Construction and Completion of the New Lutong – Kuala Baram Road Final Report, EIA. NREB Miri, Kuching.
[19] Haii, F. T., C. S. Teng, and J. M. Lulie (2001) Management of Peat Swamps. In Integrated Coastal Zone Management. eds. Chew, D., P.Sawal, and A.H. Sim. (pp.68-77), The Sarawak Press Sdn. Bhd., Kuching.
[20] Ling, Y. H. (2009) Interview by Lee, V. Z. J. Hand Record. July 23. Curtin University of Technology Sarawak, Miri.
[21] Miri Fishery Department (2009) Monthly Statistic on Fish Landing and Catchment Method December 2008, Miri.
[22] Ting, K.H. (2009) A Water Quality Study of the Miri River. Final Year Project, Curtin University of Technology.
[23] Then, S. 2008. Leakage along pipeline causes oil spill off Miri. TheStar Online, August 7. http://thestar.com.my/news/story.asp?file=/2008/8/7/nation/20080807153743&sec=nation (accessed July 20, 2009).
[24] Eco-Ideal Consulting Sdn. Bhd. 2007. National Waste Minimisation in Malaysia – Pilot Project Miri. http://ecoideal.com.my/site/modules/smartsection/makepdf.php?itemid=18 (accessed October 4, 2009).
[25] Ministry of Land Development Sarawak. 2009. Overview of Palm Oil Plantation Development in Sarawak. http://www.mlds.sarawak.gov.my/projects/PDF/Overview%20of%20Oil%20Palm%20Plantation.pdf (accessed October 4, 2009).
[26] Wong, A. (2009) Acting Assistant Senior Officer for Miri Fishery Department, Miri (Personal Communication).
[27] Department of Irrigation and Drainage. 2010. Coastal Management – Activities. http://www.water.gov.my/index.php?option=com_content&task=view&id=30&Itemid=184 (accessed February 5, 2010)
[28] Wong, A. (personal information, Aug 24, 2009)
[29] Department of Irrigation and Drainage Sarawak. 2009. Coastal Erosion Project. http://www.did.sarawak.gov.my/ksp/www/coastal_projects.htm#