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1. Introduction

Indonesia, an archipelago country lies on the equatorial area, is one of the important site to study about the “meteomarine”, especially with its monsoonal climate and Inter Tropical Convergence Zone (ITCZ), which give much influence to the global climate changes.

The western part of Indonesia has recently been taken as study sites of coastal engineering, physical geography or other related sciences, to mention among many others are Hoitink (2003) for the Bay of Banten, Java Island, Kunzmann (2002) for the West Sumatra coast, Tomaschik et al. (1997) and Whitten et al. (1987) for the ecology of Sumatra. Those studies also supported by neighboring region or country of studies in the South Asia and Southeast Asia, such as India, Malaysia, Singapore, Thailand, etc. Those scientific studies deliver much detail information as well as general acknowledge of the characteristics of Indonesian seas. Nevertheless, smaller-scale site like the Banda Aceh coast has to be investigated into more detail, especially this particular location is on the tip of Sumatera Island whereby the transitional oceanic circulation from Indian Ocean, Andaman Sea and Malacca straits takes place.

Figure 1. *The Banda Aceh City situated on the west-end part of Republic of Indonesia (Courtesy: Microsoft Corp. 2003)*

The Banda Aceh city has area of 64 km2 with 275.702 inhabitants. It is located at the latitude of $05^0 30'$ N and the longitude of $95^0 20'$ E. The city is surrounded by the Indian Ocean on the west, Andaman Sea on the north, the Strait of Malacca on the east, and by the District of Great Aceh on the South. The coastal area of Banda Aceh is located at North-west of the province, pointed out facing the Andaman Sea (Fig. 1).

Description of characteristics of the Banda Aceh beach that will be described in the following sections comprises of the following physiscal characteristics: atmospheric features (1.2), hydrospheric features (1.3), lithospheric features (1.4), biospheric features (1.5) -- which in principal are of the natural characteristics of the earth, thus, the field site -- and the human interventions (1.6), which is describing the morphological changes of the beach due to human intervention to the existence of the nature. The overall important remarks of the Banda Aceh beach are being concluded in section (1.7). Some literature studies are also supporting the descriptions of the revealed characteristics.

1.1. Characteristics of Atmospheric Features

The wind and the atmospheric pressure variations are responsible for generation of waves, wind set-up and surge as well as wind-generated currents. In other words, the winds give impact on the hydrodynamic conditions. Furthermore, the wind has a direct impact on the morphology of a coastal area through wind transport of sand on the beach and in the dunes (Mangor, 2001). In the following subsections, the characteristics of atmospheric features are being described.

1.1.1. Monsoonal climate

The Indonesian Archipelago lies on the equator, which typical monsoonal climate occurs, and converges with the Inter Tropical Convergence Zone (ITCZ). The monsoon climate is characterized by seasonal wind directions. During summer, local depressions over tropical landmasses cause the wind blows from the sea towards land. The Inter Tropical Convergence Zone (ITCZ) reinforces these tropical summer depressions (Mangor, 2001).

In the Southeast Asia the summer monsoon is referred to as the SW-monsoon. The summer monsoon is warm and humid. The winter monsoon, which is caused by local high pressure over land, blows from land towards the sea. In Southeast Asia the winter monsoon is referred to as the NE-monsoon.

1.1.2. Rainfall pattern

In general, the monsoonal climate in Southeast Asia is normally correlated to the rainfall pattern. The wet (rainy) season is when the wind comes from the ocean, during the warm season (summer), the dry season is when the wind comes from land, during the cold season (winter).

Over much of the island in Sumatra, the driest months are normally associated with the north-easterly monsoon between December and March, and the main rainy season usually falls during the transition period before the north-easterly monsoon and after the south westerly monsoon which last from May to September (Whitten et al., 1987). In the case of Banda Aceh, it is complicated because Banda Aceh is located on the tip of Sumatra Island (correspondence to Mangor, 2004). However, the northern tip of Aceh has the Asiatic type of climate with a pronounced dry season in February (Scholz, 1983 in Whitten et al., 1984).

1.1.3. Some other climate characteristics

The temperature upland is 26.4^{0}C, with the humidity as high as 79%. The wind speed in average is 233 km/day, with the sun radiation is 44%. The amount of precipitation is 1.617 mm. (UP-PSDA, 2003).

1.2. Characteristics of Hydrospheric Features

Wind blows over the surface of the sea upon its complex of bottom topography (bathymetry), resulting waves and currents, coincides with tides, as the earth continues rotating, and generates waves which gradually transforming as they approach the coast. The characteristics of these hydrospheric features create the dynamics of the coastal zone.

1.2.1. Sea water depth

As it is situated facing the Andaman Sea, the bathymetry of the coastal zone is unique. The Andaman Sea has a complex bottom topography that is characteristic of back-arc basins. In the northern region, the submarine delta has been built by the outflow of the Irrawaddy and Salween rivers, which is connected to the eastern shallow shelves along the Malay Peninsula and the Malacca Strait. From the shelves, the sea bottom drops off sharply into a large central and two smaller basins deeper than

2000 m extending along the north-south island arc. The maximum depth is 4180 m located at the south end of the central basin. Because the sill depths of channels across the Andaman-Nicobar Ridge are shallower than 1800 m, the deep water of the Andaman Sea Basin is isolated from the Bay of Bengal and its water temperature remains as high as about 5^0C down to the bottom (Nozaki and Alibo, 2002).

Having view point from the Banda Aceh beach, the bathymetry of the sea comprises the narrow continental shelf (0 – 200 m) with average distance from shoreline is of 5 km, gradually followed by a narrow transition of continental slope (for about another 2 km) before deepened into the abyssal plain (1000 – 2000 m depth) of the Andaman Sea. An oceanic volcano or seamount is positioned at the adjacent of We Island up north (Salm and Halim, 1984 in Thomascik, 1997). In the near shore, from the latest bathymetric measurements in 2003 by Hydraulic Laboratory of Syiah Kuala University (UP-PSDA, 2003), the 10 m depth is as far as 2 km from the average shoreline.

1.2.2. Wave climate

On the preparation of the Alue Naga Floodway Channel Project, in 1990, a survey of wave climate at Alue Naga Beach was conducted, resulting the wave measurements data set for one year, from June 1st 1990 to May 31st 1991. The measurement results obtained as a tabular of daily significant wave heights, periods and directions (unpublished data source from *Civil Work Department – Management and Maintenance of Krueng Aceh River*, 1991).

From the record, the highest significant wave is of 1.0 m height with a period of 4.3 s which was occurred in August 1990 which predominant direction of the wave was from the northwest (54%), which occurs in the half later of June 1990 through half early of October 1990. It is more or less corresponds to the "rough" warm season of the monsoonal climate. On the other hand, the second predominant wave direction is from the northeast (40%), which occurred in the later of January 1991 to May 1991. It is agreed with the "calm" cold season of the monsoonal climate. The recorded data of significant wave heights and directions are obtained in a wave rose in table 1 and Figure 2.

Table 1. The wave percentage of wave directions on the Banda Aceh beach during June 1990 – May 1991

Wave Height	Wave Direction (%)					
(m)	W – E	NW - SE	NW - SW	N - S	NE - NW	NE - SW
0 - 0.2	0.00	1.53	0.00	0.00	0.31	2.75
0.2 - 0.4	0.61	13.46	2.45	0.00	4.59	14.37
0.4 - 0.6	2.45	6.73	1.53	0.00	0.61	1.22
0.6 - 0.8	2.14	10.70	3.67	0.31	1.83	2.75
0.8 - 1.05	0.92	7.65	5.81	0.00	1.83	9.79
total percentage	6.12	**40.06**	13.46	0.31	9.17	**30.89**
total data	100					

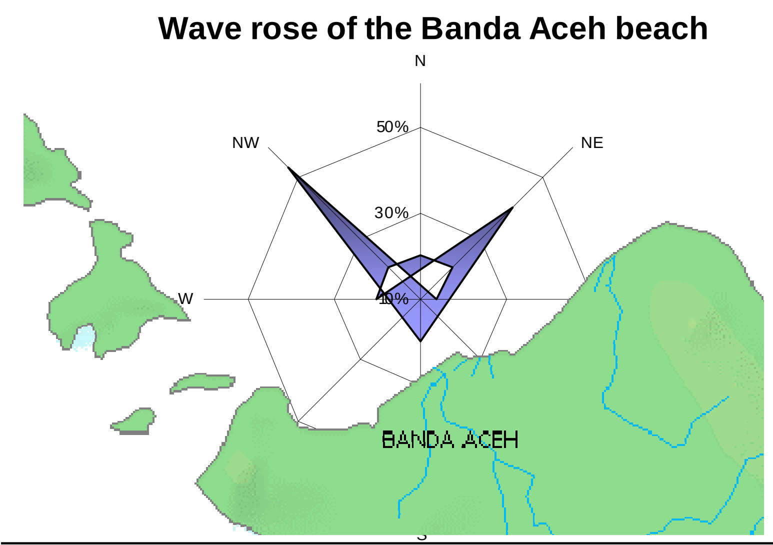

Figure 2. *The wave rose of the Banda Aceh beach from the recorded wave climate data during June 1990 to May 1991.*

The rest of other directions are less important due to the small percentages and heights. The transitional wave direction occurred between December and January for “rough” to “calm” and between May and June for “calm” to “rough”. The information about how the measurement was carried out in the field is unknown.

1.2.3. Rivers

There are two important branches of Krueng Aceh River, with average of 1300 m^3/s discharge, flow to the sea contributing abundant sediment materials to the littoral zone. The first branch, which namely also Krueng Aceh river, which flow capacity is of 400 m^3/s discharge, which is now still remain as a natural inlet and the river mouth is utilized for traditional fishery port. Another branch of the river which flow capacity is of 900 m^3/s discharge, whereby since 1991 has been utilized as the floodway channel to drain the flooding on the Banda Aceh city during the rainy seasons (unpublished data obtained from *The Project of Alue Naga Floodway Channel*, 1990).

There are also two other natural inlets, i.e, Krueng Cakra River and Peukan Bada River (see segments in the appendix 1). The Krueng Cakra River is a short single river, which river mouth is naturally shaped as lagoon, linking to Deah geulumpang lagoon parallel to the shoreline, adjacent to several square meters of wetlands. Another single natural inlet is situated on the low-lying of the Peukan Bada Beach, namely Peukan Bada River, which also surrounded by several hectare of wetlands.

1.2.4. Tides

The tides are categorized into semi diurnal tides due to the presence of twice a day highest and lowest water levels. Some recorded data of tidal measurements are obtained from the measurements on different locations along the Banda Aceh Beach, which were conducted by Hydraulic Laboratory of Syiah Kuala University through some projects.

1*. Tidal records on Krueng Aceh Rivermouth.*
The measurements location took place on the center point of Krueng Aceh River mouth about 50 m upstream from the tip of the jetty (see yellow spot in Fig. 7). According to the interviewed surveyor, the location was chosen because it is calm enough for a good measurement to get the tidal constituents. The measurements were conducted for every hour within 30 days from August 28^{th} to September 27^{th} 2003.

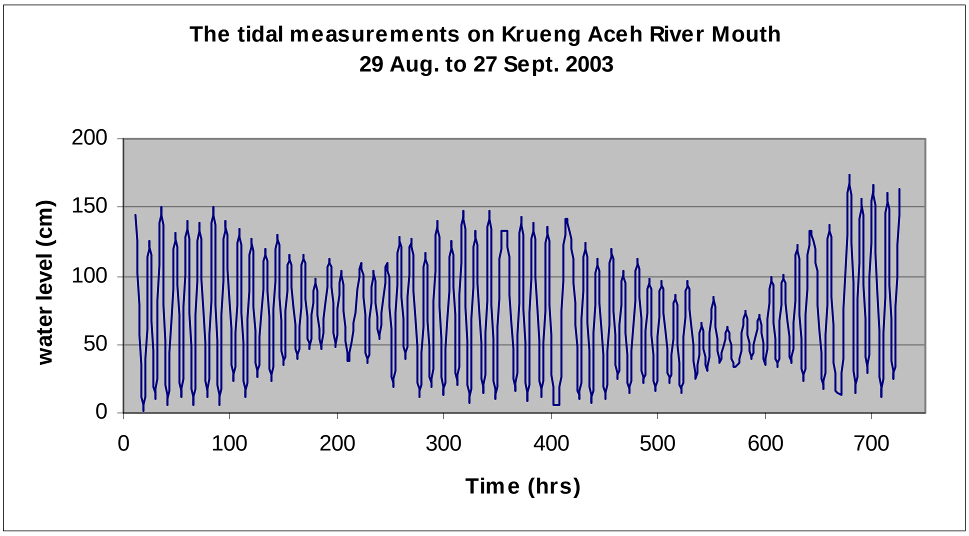

Figure 3. *The measured and predicted tidal graphic (28 Agustus – 27 September 2003)*

Figure 3 shows the measurements results, which revealed that the type of the tidal in this location is semi diurnal, by means there are two high waters and two low waters everyday. The mean spring tidal range (MSR), i.e. the range between MHWS and MLWS, at Syiah Kuala beach is 1.10 m high. Furthermore, the Mean Low Water Spring was being used as reference point of ± 0.00 for the bathymetry and topography measurements.

In Anonymous (2003), the tidal prediction result by using the Least Square Method program revealed the amount of the tidal constituents as; M_2 = 0.3247 m, S_2 = 0.2365 m, N_2 = 0.1335 m, K_2 = 0.1285 m, P_1 = 0.2263 m, K_1 = 0.1168 m, O_1 = 0.0552 m, M_4 = 0.0056 m, and MS_4 = 0.0022 m. Regarding the predominant tidal characteristics at the site to be semidiurnal, let the M_2 constituent to be put into prominent consideration.

Using the computed world-wide amphidromic systems for the dominant semi-diurnal lunar tidal component M_2 (Open University, 2002), it reveals that the prediction of tidal constituent M_2 of the Syiah Kuala Beach agreed with the computed world-wide amphidromic co-range lines (0.25 – 0.5 m), which would validate the tidal measurements conducted by the Hydraulic Laboratory of Syiah Kuala University.

According to Mangor (2001), the tide can be characterized by the tidal range, or just the tide, which is the difference between characteristic tidal levels such as the MHWS – MLWS. The magnitude of the tide at a site can be categorized as follows:

Macro tidal regime:	tidal range > 1.5 m
Moderate tidal regime:	tidal range 0.5 m – 1.5 m
Micro tidal range:	tidal range < 0.5 m

Accordingly, the tide characteristic of the Syiah Kuala Beach is categorized into moderate tidal regime.

2. *Tidal records at Ulee Lheue*

Another tidal measurement on Ulee Lheue Beach were taken from 22 July to 21 August 2001, in the purpose of the Ulee Lheue Ferry Port constructions. Figure 4 displays the graphic of the tidal measurements (dashed line) and the prediction (continued line) by using the Least Square Method (LSQR), which both were conducted in Hydraulic Laboratory of Syiah Kuala University.

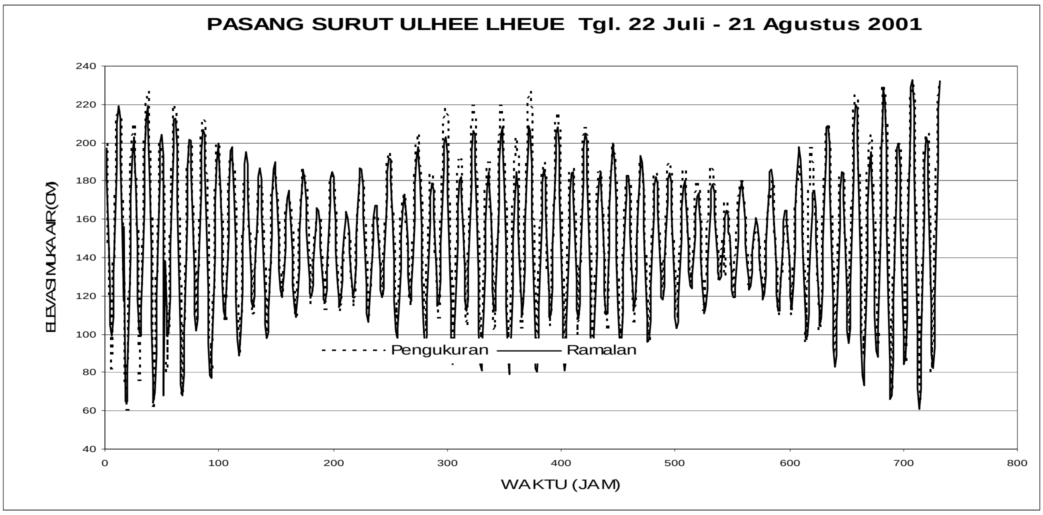

Figure 4. *The measured and predicted tidal graphic (22 July – 21 August 2001)*

From the graphic, the resulting normal tidal range is 0.54 m high or 1.11 m high. Accordingly, the tidal characteristic is categorized into macro tidal regime.
A similar categorization can be made for the storm surge conditions at a given site. The coastal morphology at sites with a macro tidal regime is normally much influenced by the tide and this is often reflected in wide tidal flats.

1.2.5. Water Quality

The water quality measurements were conducted at the same time and the same location for the sediment measurements. The measurements were conducted twice, i.e. during the full moon and the new moon, at a certain location prior to and after the wave breaking.

The method of measurement used was the integrated method, where sample were taken on the surface of the sea, which parameters observed were considered to be distributed evenly to the whole depth. Those parameters are including pH, temperature, DO (Oxygen concentration in water) and turbidity. The overall results of the measurements are listed in table 2.

Table 2. Water quality test results

No.	DO (ppm)	Turbidity (ppm)	Temperature (^{o})	pH	Location
I	3.7	96	26.9	6.54	BBZ, ST_P
II	3.3	89	26.9	6.55	BBZ, ST_P
I	3.0	116	26.9	6.65	BBZ, ST_M
II	2.6	105	27.2	6.61	BBZ, ST_M
I	3.5	99	27.2	6.54	SZ, ST_P
II	2.6	92	27.0	6.63	SZ, ST_P
I	2.0	111	27.0	6.58	SZ, ST_M
II	2.2	130	27.0	6.61	SZ, ST_M
I	2.6	135	26.6	6.57	SZ, N
II	3.3	146	26.6	6.54	SZ, N

Note:
BBZ = Beyond Breaker Zone (towards the sea)
SZ = Surf Zone, (after wave breaking)
ST_P = Spring Tide
ST_M = Neap Tide

1.2.6. Surface current

In general, sea water currents change direction relative to the monsoonal seasons, but fig. 5 shows that the Straits of Malacca experience a south-east current throughout the year and the west coast of Sumatra a north-west current. However, the coast of southeast Sumatra has a north/north-west current in February and a south/south-east current in August. The western coast of Aceh and some of North Sumatra experience the opposite change in current. It can be seen that most of the water from rivers on the east coast will flow to the north-west and water from rivers on the west coast to the south-east (Whitten et al., 1987).

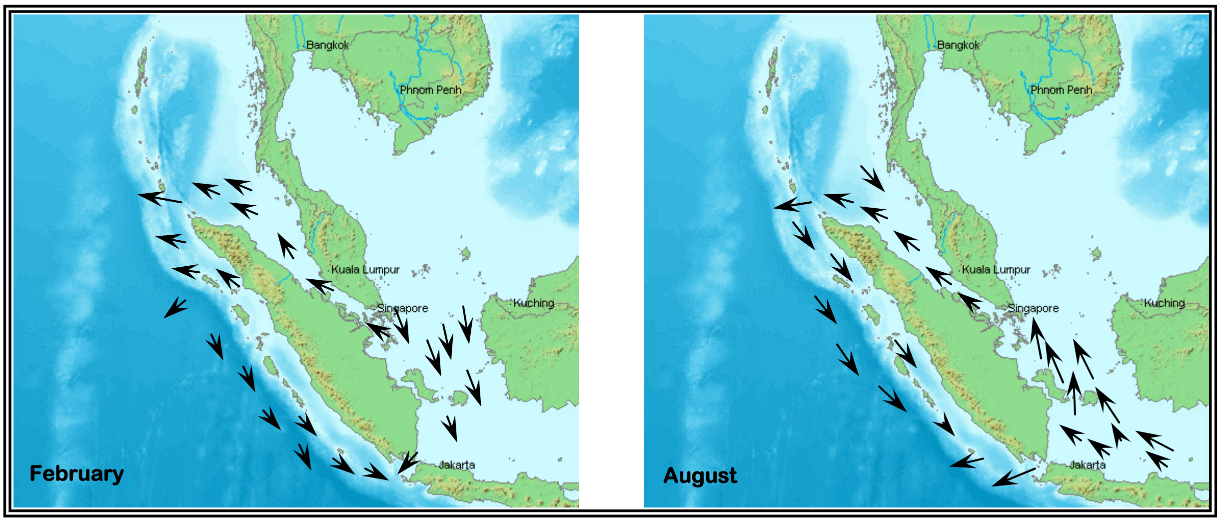

***Figure 5**. Surface currents around Sumatra in February and August (After Wyrtki, 1961 in Whitten et al. 1987).*

Nevertheless, due to its position facing to the northwestern sea, the Banda Aceh beach experience uncommon current surface direction compare to the above statements. In fact, the water from rivers on the coast, as well as the development of the sand spits on Krueng Cakra river mouth and the accretion and erosion pattern on Krueng Aceh river mouth are directed to the northeast.

A set of measurement data of surface currents is obtained by Hydraulic Laboratory of Syiah Kuala University. However, the drawback of the conducted measurement was that it observes at only one point which measurements were taken every one hour over 25. According to Horikawa (1988), by repeating the work at some intervals (50 m or 100 m) alongshore, an overview of the long shore current and the positions of rip currents can be obtained. Nevertheless, the results indicated that the current directions are directed commonly to the northeast, which magnitude varies between 0.19 m/s and 0.73 m/s during the full moon, and between 0.18 m/s and 0.58 m/s during the new moon.

1.3. Characteristics of Lithospheric Features

1.3.1. Topography

The Banda Aceh beach is semi-exposed to the transition of Indian Ocean to Bay of Bengal, Andaman Sea and Malacca Straits. Furthermore, there is also extension of some small islands from Republic of Indonesia territorial boundaries (Breueh Island, Nasi Island, We Island (Sabang)) to Nicobar and Andaman Islands (Fig. 6). Even though it seems to be quite protected by those islands, nevertheless, the beach still severely damaged by erosions and abrasions.

Figure 6. *The position of the Banda Aceh beach facing towards the Andaman Sea and bordered by Andaman and Nicobar Islands. (Courtesy: Microsoft Corp., 2003).*

The beach is about 25 km long which profile slope between 1:30 and 1:50. These plain sandy beach is situated between two headlands; Ujong Pancu headland and Ujong Batee headland (see the segmentation of the beach in the appendix 1). The hinterland of the area is relatively flat with elevation from – 0.5 m to + 4.5 m of mean sea level (UP-PSDA, 2003).

1.3.2. Low-lying areas

The Banda Aceh beach has a typical low-lying coastline, which in natural consists of some estuaries and tidal inlets which gradually take form of shallow lagoons in front of a stretch of elongated sand spits and some small barrier islands (in the vicinity of the Alue Naga floodway channel). Those low-lying areas are extended further to the hinterland forming the wide spread of wetlands. The prominent changes of its shoreline can be distinguished between before and after the construction of Alue Naga Floodway Channel. Those changes will be discussed further in subsection 1.6.2.

1.3.3. Sediments

The Banda Aceh beach, in visual, is well-known as a sandy beach, with grain sizes can be seen in Table 3. The measurements took place at the tip of left and right jetties of Krueng Aceh River Mouth during the spring tides and the neap tides, as can be seen in Fig. 7.

The sediment samples were taken at the location I and II in Figure 6 during the survey of Syiah Kuala Beach Detail Engineering Design Project in 2003, by using a sediment trap, which sediments were trapped in 30 cm depth. For each locations, the sediment samples were taken at a location beyond the breaker zone (towards the sea), and at a location on the surf zone (after wave breaking). The samples were taken to the Soil Mechanics Laboratory of Civil Engineering of Syiah Kuala University to be tested for the grain density and using sieve analysis test to have grain sizes.

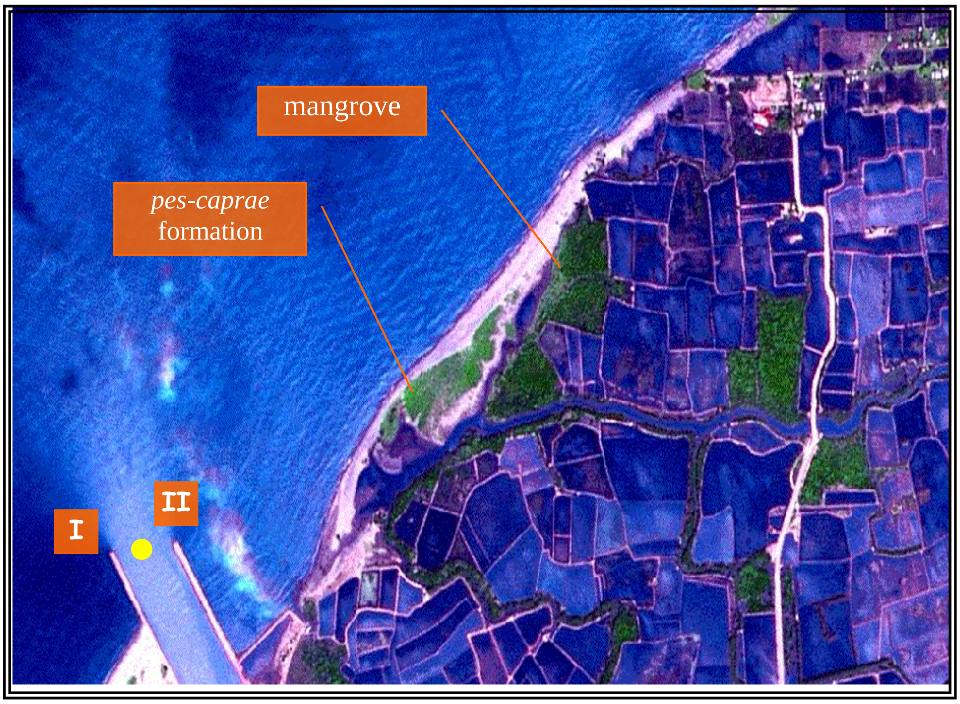

Figure 7. *Location of measurements for tides on Krueng Aceh River Mouth*.

Table 3. The sediment grain sizes sample measurements (Hydraulic Laboratory of Syiah Kuala University, 2003).

No.	Specific Gravity	D_{35} (mm)	D_{50} (mm)	D_{90} (mm)	Wave conditions
I	2,78	0,144	0,174	0,301	BBZ, ST_P
II	2,71	0,09	0,11	0,158	BBZ, ST_P
I	2,70	0,126	0,145	0,302	BBZ, ST_M
II	2,70	0,09	0,117	0,158	BBZ, ST_M
I	2,88	0,132	0,158	0,224	SZ, ST_P
II	2,74	0,135	0,141	0,214	SZ, ST_P
I	2,80	0,162	0,182	0,316	SZ, ST_M
II	2,72	0,126	0,158	0,263	SZ, ST_M

BBZ = Beyond Breaker Zone (towards the sea)
SZ = Surf Zone, (after wave breaking)
ST_P = Spring Tide
ST_M = Neap Tide

From the above information, it reveals that the type of the sediment taken was bed load sediment. However, sand traps for bed load are not applicable for long-term measurement because the bottom level changes in time (Horikawa, 1988).

Table 3 shows the grain sizes in average of the sediment at the location I are larger than the one at the location II. Having coincided with the Fig. 7 where reveals the sediment accumulation on the left hand side of the jetty while the right hand side of the other jetty on the Krueng Aceh River mouth is eroded, explains the direction of the littoral drifts or long shore transport is predominantly from the west to the east. The average grain sizes are between 0.09 mm to 0.32 mm, which categories into very fine to medium sand (Open University, 2002).

1.4. Characteristics of Biospheric Features

In this section, biospheric features on the coastal area are described.

1.4.1. Beach vegetations

Destruction of fringing coral reefs and the commercial exploitation of sand (such as near Banda Aceh) can almost totally destroy beach vegetation. By their pioneer nature, however, the smaller plants can recover quickly, particularly in the *pes-caprae* association (Whitten et al., 1987).

The vegetation of the beach is mostly the Beach Morning-Glory (*ipomoea pes-caprae*), which covers sandy dunes along the accreting coasts. The belt of vegetation is merged with the mangrove and some small portion of the *barringtonia* formation further to inland, which in fact a typical of wide low-lying area.

On some segments of the beach, such as the Cermin beach and the Alue Naga Beach are also vegetated by sea conifers, which were purposely planted. Nevertheless, almost the entire hinterlands by means the wetlands, used to be mangrove habitat, and some portion of them still exist at present, such as at the wetland of the Lam Badeuk beach, Krueng Cakra riverbanks, and at the wetland of Syiah Kuala beach. The mangrove grows further to the hinterland along the river banks and the vicinity of the wetlands whereby the saline soil water still effective.

A quite complex characteristics of vegetation due to the unique coastal landscape is found on the Syiah Kuala beach (Fig. 7), where the *pes-caprae* formation exists in front of the *barringtona* formation and large trees sprawl across the about 1 m high cliff (wall) behind it, and on the gradually lower ground, the mangrove forest spreads over the wetlands.

According to Whitten et al., 1987, the *barringtonia* formation is found on the abrading coasts where sand is either being removed by unhindered ocean swells or where sand has at least ceased to accumulate; in such areas a beach wall about 0.5 – 1 m tall is formed. Those formations of vegetation and the coastal landscape more or less support the fact of such a complex history of morphological changes of the shifted accreting-abrading beach.

1.4.2. Sea animals

Upon the typical Sumatra beach, a great many small animals live permanently within the sand where they have some protection. Near the high water level burrows about 8 cm across can be found with small piles of sand around them. Their occupants are adult, beige-colored sand crabs *Ocypode ceratophthalma* which are rarely seen during the day. Young *ocypode* are very numerous and can be seen on the sand surface both by day and night. (Whitten et al., 1987).

The variety of fish and underwater animals are wide inside the Andaman Sea and Indian Ocean, where the traditional boats land more than 3000 ton ocean water fish per year (source: Information on Fisheries Management in The Republic of Indonesia, 2000), regardless the amount gained by some illegal fish boats from the neighboring country.

The We Island across the sea is well-known with its variety of coral reefs, and some typical of barrier reefs and fringing reefs are also found on the western and eastern coast of Aceh. The condition is contrary to Banda Aceh beach, which is merely a sandy beach. According to Whitten et al., 1987, all the seas around Sumatra are warm enough for coral but the clarity and salinity of conditions are not met where large rivers flow into the sea. These rivers reduce the salinity and their sediment loads causing increased turbidity which in turn reduces light penetration.

1.5. Human Intervention

The dynamic nature of the archipelago, in terms of its geology and climate, directly influences the inputs of nutrients and trace elements into the seas through volcanic activity, sedimentation, and in recent history, large amounts of soil eroded from areas under human influences (Tomaschik et al., 1997).

In this section, several relevant human activities are described. Some aspects, such as beach vegetation, land use changes and coastal protection works are overviewed, related to somewhat chronological interference by human action on the coastal area.

1.5.1. Wetlands and beach vegetation existence

The removal of beach vegetation may not be regarded as a particularly serious loss in itself, but its ability to hold together a loose sandy substrate means that in its absence more or less continuous coastal erosion occurs. The erosion and the impact on human settlements are particularly serious during bad storms, because the power of the wind and waves is no longer countered by deep-rooted vegetation (Whitten et al., 1987). However, the establishment of the ponds requires the removal of mangrove. Furthermore, large scale disturbance of mangroves can lead to coastal erosion because the shoreline is no longer protected by trees. The shore may be reduced to a narrow sandy beach or to inhospitable saltpans. The coastal population centers are then more susceptible to the effects of storms such as flooding.

During the past decades, as the demand of more lands for housing, the unproductive low-lying areas of some part of the beach (such as low-lying area of Kahjue beach) have been utilized for real estate site. Meanwhile, the more promising of the productivity of fish ponds, the more the wetland extended to be utilized as fish ponds. The considerable planned area is on the Lambadeuk beach, which 250 hectare wetlands are functioned as intensive fish ponds (source: http://www.kimpraswil.go.id). Consequently, the removal of mangrove becomes more and more intensive.

Deah Geulumpang beach (see appendix 1) was used to be a waste dumping area of the city. Since the new ferry port was established, the dumping area was then relocated to the eastern part of the beach (before it meets Krueng Cakra river mouth).

1.5.2. Port and sea defense works

Besides interruptions of natural inlets and floodway channel, since 2001 a new ferry port has been constructed which operation starts at the end of 2003. The Ferry port is located on the existing lagoon (Deah Geulumpang Lagoon) which port basin was design with dimension of 200 x 400 m width, and 5.5 m depth (Fig. 8a). The mouth of the port basin has a 100 m, with two-sided jetties extended to the sea (UP-PSDA, 2000).

Several kind of coastal structures by means protection were constructed along some part of the beach, and also on some river mouth. Since the Colonial age, Ulee Lheue (a small city near by the sea between Krueng Cakra River and Deah Geulumpang Beach, about 5 km away from the city center) was well-known as Port city up until 1976, then the port was then removed to the Eastern coast of Great Aceh County, namely Malahayati Port, which is located 40 km away from the city center.

(a) (b)

Figure 8. *The aerial photographs of the Banda Aceh beach, reveal closer look to Ulee Lheue Ferry Port (a) and Alue Naga Floodway Channel (b), with the lagoon and wetlands on the coastal area. (Courtesy : Hydro Laboratory of Syiah Kuala University, Banda Aceh).*

Some protection structures of the 'Colonial' port facilities, however, still exist, such as seawalls on the side of Krueng Cakra river mouth, extended further before Cermin Beach, and the other buildings on the shore, such as dockyards. Nevertheless, due to aging and storm events, the seawalls have now been severely ruined down (Fig. 9). In recent years, before the construction of the new ferry port, a set of seawall was installed along the eastern part of the Cermin Beach.

However, in recent years, the local government has decided to reestablish the port back in Ulee Lheue by construction of the Ulee Lheue Ferry Port. The ferry port, which is protected by mound breakwater, utilized for the transportation between Banda Aceh city to We Island (Sabang), where a Free Port has been reestablished. The construction of the ferry port was started in 2000 and operated from 2003 until present.

On the east side of the ferry port, there has been partly-established groin field along the Deah Geulumpang beach (Fig 8a). A pair of jetties was installed on the Krueng Aceh river mouth to reserve the depth of navigation and also on the Alue Naga Floodway Channel to control the sedimentation on the mouth of the channel.

1.5.3 Floodway channel

In 1991, the Alue Naga Floodway Channel was constructed by means regulating one of Krueng Aceh river branches across the wetlands of Alue Naga beach (Fig. 8b). It was constructed in the purpose of draining the upland area from annual flood in Banda Aceh. After the construction of the floodway channel, the morphology of the beach was considerably changing due to short-cutting of the lagoon to let the flood from the upstream runs into the sea.

1.5.4 Morphological changes of the beach

In order to have a clear view of how the Banda Aceh beach has been experienced its morphological changes through decades, the difference of shoreline features from two different time of maps are shown in Fig. 9.

In the old map of Banda Aceh (Fig. 9a), the coastline of the beach consisted of two prominent inlets, one of them was the Krueng Aceh River (at about the center of the beach) and the other one was a tidal–type inlet which was parallel to the beach (on the right hand side). Evolving through decades with the coastal processes, the shoreline on the later particular area was formed with barrier islands, which the largest one was elongated parallel to the shore, and some other small ones were protected in the lagoon area (Fig. 9b).

Figure 9c reveals that the wetlands becomes increasing towards the hinterland, while the coastal processes continue, the inlet of the existing lagoon on the left-hand side of the floodway channel

has been closed forming a narrow strip of beach (see also Fig. 8b), while another inlet on the right remains to be opened.

Furthermore, the wetlands on the low-lying area were not as wide as it is at present. In addition, on the left-end side of the beach (the Lam Badeuk beach; see the segments in appendix 1), the land facing the shore was a dried land, while at present has become the wetted land (Fig. 9b).

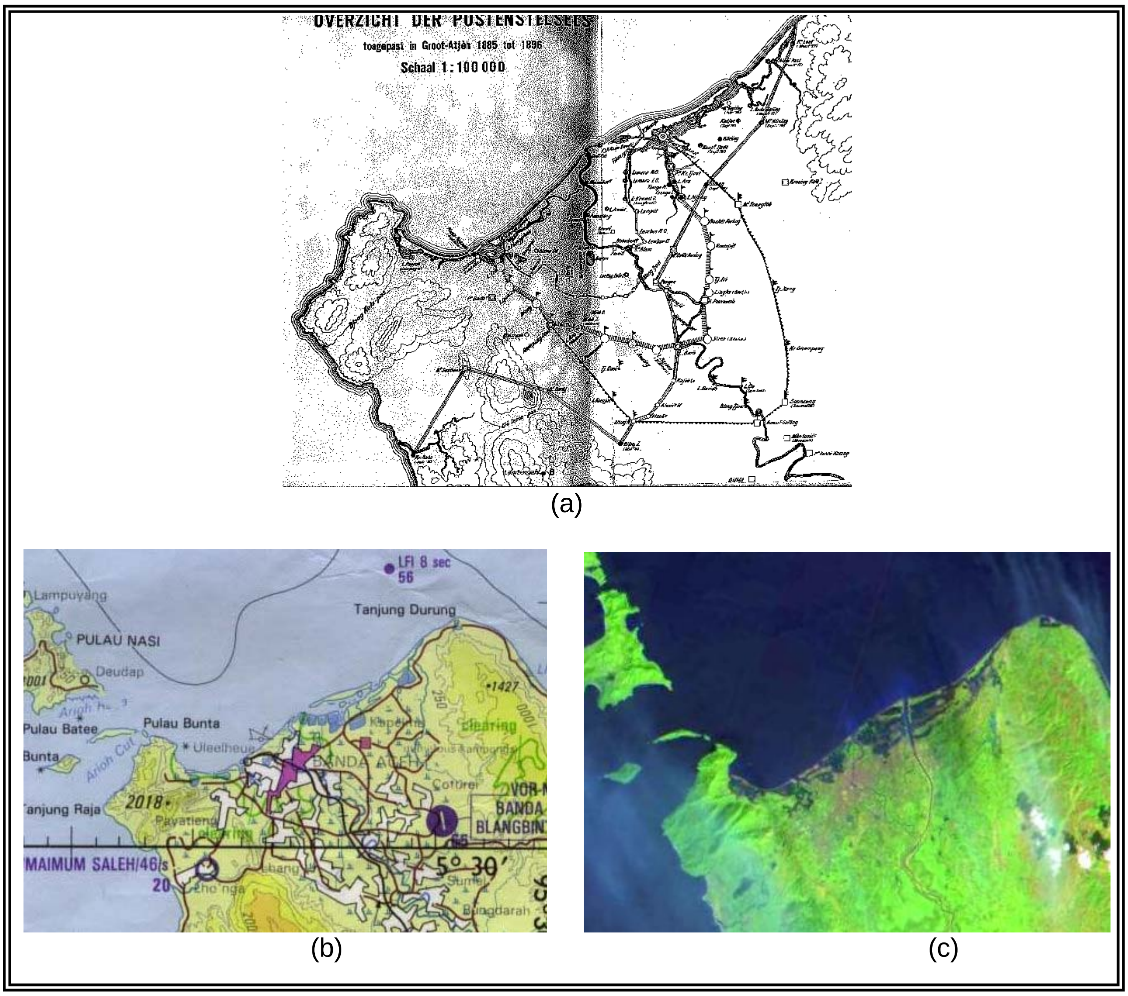

Figure 9. *The morphological changes of the Banda Aceh beach in the Colonial age (a), before and after the construction of the Alue Naga Floodway Channel (b and c, respectively). Courtesy: (a), (b) Portion of Defense Mapping Agency TPC L-9B 1990, and (c) courtesy by SPOT 5 Satellite Image taken on January 11^{th} 2003.*
The construction of jetties on the Krueng Aceh river mouth has led to severe erosion downstream (assuming the predominant long shore sediment transport is from west to east). On the downstream of the jetties (Syiah Kuala beach), there used to be mangrove forest on the wetland area, which gradually disappears, along with the lost of beach strips. The mangrove trees were gradually dead and drifted away to the east, leaving the trace of their pieces on Syiah Kuala beach after the storm.

1.5.5 Characteristics on beaches

Lam Badeuk beach (segment 1)
The strip of the Lam Badeuk Beach is now developing towards the sea and pointed to the front of the river mouth, making the closure almost half of the river mouth's width. At only one event (which suspected occurred on the spring tide), some parts of the land was submerged, leaving a delta shape on the centre of the river mouth. This phenomenon happened periodically in every month.

Cermin beach (segment 2)
Some parts of Pantai Cermin beach, at the adjacent to Krueng Cakra River mouth are protected by coastal structures (sea wall), which was build in Colonial age. At present, due to the aging and

intensely storm attack, the structure has been decayed severely. The most effort by the government to cope with the decay was to insert some materials like stones on the toe of the decayed structure, and at the location where the top of the existing structure was located.

In 1998, an attempt by the local government to protect more of the hinterland due to flooding by run-up of the sea wave was done by installing sea wall along almost the entire part of Cermin Beach, which then remains only a small portion for recreational area. The government was facing dilemma between surviving the hinterland area by flooding during the high tide and storms (where there are many households located less than 100 m from the shoreline), and the natural beach existence.

Deah Geulumpang beach (segment 3)
At the adjacent of the ferry port, there is another strip of beach (Deah geulumpang beach). Since the ferry port suspected to interrupt the long shore sediment transport, some groins had been installed along the beach to stabilize the shoreline from being eroded.

Syiah Kuala beach (segment 4)
This strip of beach is rather flat and the shoreline changes significantly (50 – 100 m) between the high tide and the ebb. Further to the hinterland, some small dunes was developing for many years, and some other part of the hinterland there was small cliff, which in late 1990's, still untouched by the run-up, but today, as the beach strips getting narrower, the cliff is suffering from severe erosion.

An attempt to protect the cliff was with the installation of beach protections made by concrete-filled cylinder. However, during the big storm attack in 2003, the protection has been collapsed. On the Kuala Beach area, there is a preservation site of Syiah Kuala cemetery (the former Islamic apostle), one of the important historical site of Banda Aceh.

Kahjue Beach (segment 5)

Kahjue Beach is located on the adjacent (Eastern part) of Alue Naga floodway. If we take a look at the map on Fig. 8b, we can see that it is a low land area with lagoons and wetlands, and narrow beach strips. As the growth of demands of housing has been increasing for the last decades, the inland area, which however used to be fish ponds, nowadays has been utilized as real estate with low standard quality in fresh water distribution.

Lam Bada Beach (segment 6)
Neighboring Kahjue beach, there is another beach namely Lam Bada Beach. There is no certain border in between as far as the author concerned. However, the characteristics of the beach in general are similar to the adjacent beaches, i.e., low lands and lagoons, except in this particular segment of the beach, most of the coast are utilized for traditional fisheries on the lagoons and fishponds. In addition, there is a centre of fish auction which actively used for fish distribution for the local and outside the region, and the lowlands also utilized by the community for traditional salt mining.

1.6. Concluding Remarks

The Banda Aceh beach experiences the typical monsoonal climate, which has two seasonal predominant wave directions. Due to its unique position on the tip of Sumatra Island, the surface current pattern tends not to follow either of general patterns of west or east coast of Sumatra. This fact may lead to complicated sediment transport processes.

The sediment supply on the littoral zone is suspected to be dominantly from the river. The near shore bottom slope is quite mild with depth of 10 m over 2 km distance from the shoreline (1:200). Further to inland, the slope is even rather flat, letting the tidal and storm running far enough upland.

Regarding the characteristics of its low-lying area, the semidiurnal tides with tidal regime as to be categorized into macro tidal regime, and also the mildly wave climate for the whole year, the beach is hypothetically categorized as tide-dominated, with respect to the incidental storm event which frequency is yet unknown at present.

The mangrove grows further to inland, in spite of seaward, which explain its significant role to the life on the wetlands rather than as natural sea defense. The existence, however, gradually decreases in recent years, replaced by intensive fishponds and housing. Regarding the beach vegetation type related to the low-lying areas in some different time of maps, the beach seems to experience a long term shifting of accretion-abrasion phase.

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