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Sea Level Rise Impacts and Adaption Measures for Sandakan, Sabah

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ABSTRACT: Sea level rise (SLR) can give various impacts such as inundation in the low-lying areas, increase the coastal erosion and extreme events such as storm surge, wave overtopping, salt intrusion and damage to existing coastal infrastructure, hence affects the socio-economy and the livelihood of the coastal communities. The projected SLR along the Sandakan coast for the year 2020, 2040 and 2060 are 0.1 m, 0.25 m and 0.5 m, respectively. This study was carried out to assess the impacts of SLR to Sandakan coast for 2020, 2040 and 2060; and to recommend some relevant adaptation measures to reduce the impact. Hydrodynamic model with simulations of 2020 and 2040 projected SLR show no significant change in Sandakan Town when compared to the existing condition, probably due to its high platform level. However, model simulations for 2060 projected SLR show that the wave heights may increase by 0.18 m compared to the existing 2.6 m, although the wave heights in Teluk Sandakan will not change much. Similarly, the maximum current velocities will increase by 0.15 m/s in 2060, compared to the existing condition of 0.3 - 0.5 m/s. Overall, more impacts of SLR can be observed at Pulau Duyong due to its low-lying area. There will be a reduction in land area; about 958 hectares out of the existing 1,800 hectares of mangrove forests and coastal vegetation will be lost due to inundation and erosion, generated by the 0.5 m projected SLR in 2060. Construction of railings, low walls and rock bunds are recommended as an adaptation measures to ensure the safety of the people living along the Sandakan coast. There is also a need to raise the bund and platform levels for jetties and slipways at the Marine Police Complex to avoid inundation. The estimated cost for the recommended adaptation measures is about RM18.25 Million.

Keywords: Malaysia, Impact, Inundation, Adaptation, Wave, Current

1 INTRODUCTION

In 2010, the National Hydraulic Research Institute of Malaysia (NAHRIM) had carried out "The Study of the Impact of Climate Change on Sea Level Rise in Malaysia" where Sea Level Rise (SLR) Projections for the year 2020, 2040, 2060, 2080 and 2100 were produced based on the statistical analysis of the tide gauge data obtained from the Malaysian Department of Survey and Mapping (JUPEM) and satellite altimeter data observed along the Malaysian coast. The result shows that the projected SLR along Sabah coastline for the year 2100 will be between 0.6 to 1.0 m (NAHRIM, 2010).

Consequently, NAHRIM was requested by the Economic Planning Unit (EPU) of the Prime Minister's Department, to undertake a comprehensive study on the SLR impacts along Sandakan coast because of its high population; its outstanding socio-economic development; and vulnerability towards prone tsunami event and coastal erosion (TRPD, 1996; SSMP, 2005).

The objective of this study is to assess the impact of SLR to the potential hydrodynamics surrounding the coast of Sandakan due to climate change and global temperature rise. This study will evaluate the potential inundated area that may be caused by the projected sea level rise for the year 2020, 2040 and 2060; and their impacts to the low lying and risk area in Sandakan, hence recommend some relevant mitigation and adaptation measures to be implemented to reduce their impacts (EPU, 2012).

2 STUDY AREA

This study focuses on the two key locations which are most at risk i.e. the coast from Bandar Sandakan (Sandakan Town) up to the Malaysian Maritime Enforcement Agency (APMM) Jetty, involving about 2.3 km coastline; and the entire coast of Pulau Duyong (Duyong Island) (EPU, 2012). The town is developing rapidly with residential, industrial and ports. Some coastal protection structure such as the sea wall has been built to protect the coastal town of Sandakan (EPU, 2012). On the other hand, Pulau Duyong is less developed, consists of sandy beaches with gentle slope at the northern area while the southern area is muddy. About 70% of Pulau Duyong is dominated by mangrove forests (EPU, 2012). Most of the population in Sandakan comprises of fishermen, labourers and hawkers. Figure 1 shows the location of the study area which cover both Sandakan Town and Pulau Duyong.

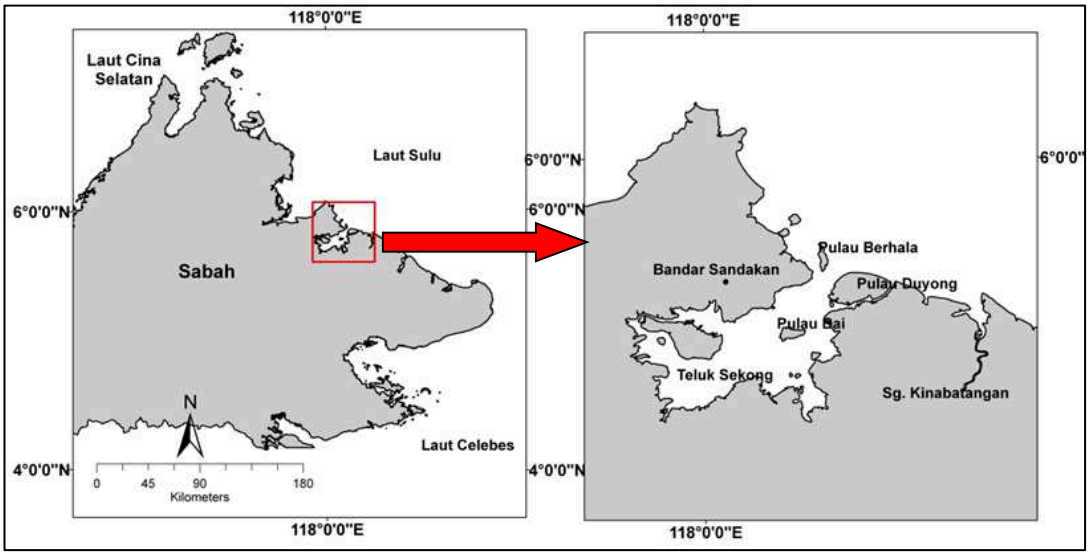

Figure 1. Location of the study area

3 METHODOLOGY

Marine data collection such as the tide level; current velocity and direction; wave height and direction; water quality; bathymetry and profile surveys; was carried out in May 2012. These data were then used as input, calibration and analysis of MIKE21 numerical model simulation to study the hydraulic behaviour around Sandakan coast (EPU, 2012).

Numerical modeling simulations were carried out based on the projected SLR for the year 2020, 2040, and 2060 with the estimated increase of 0.1 m, 0.25 m and 0.5 m, respectively; taking into account the effects of changes in tidal heights, waves and current speeds (EPU, 2012).

The vulnerability assessment of the Sandakan coast has also been done using the Management Unit (MU) approach to identify its vulnerability against the sea level rise in terms of physical, ecological and socio-economic (Figure 2). In addition, the socio-economic assessment was also carried out in the vicinity of the study area in order to obtain feedbacks from local residents regarding the issue of rising sea levels.

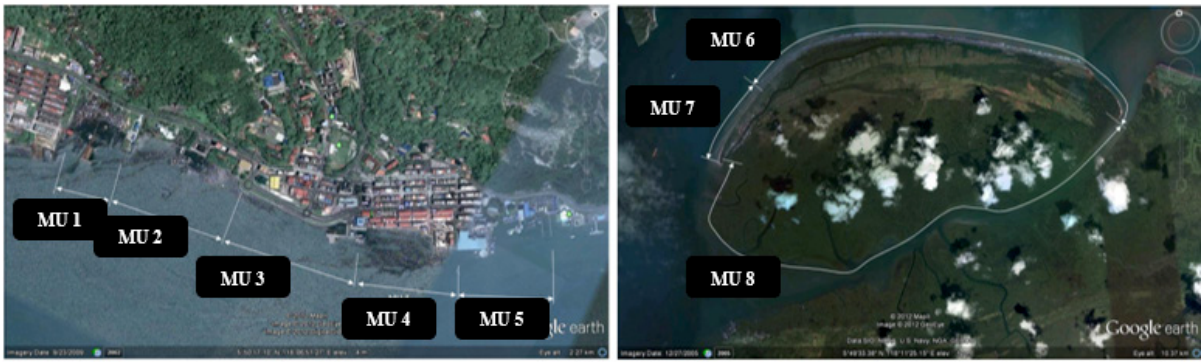

Figure 2. Management Units (MUs) for Sandakan coast: Sandakan Town (left) and Pulau Duyung (Right) (Source: EPU, 2012)

4 RESULTS AND DISCUSSION

Hydrodynamic modeling results produced some simulation parameters such as height of the water level, waves and current speeds. Based on the simulation results, it can be seen that the increased in the water level for the year 2060 is quite discernible when compared to the baseline (existing) condition.

For the baseline condition, the hydrodynamic simulation results show the maximum water level of between 1.56 to 1.92 m measured at Mean Sea Level (MSL) while the maximum water level for the 2020 projection is between 1.68 to 2.04 m (MSL) (EPU, 2012). Similarly, the maximum water level for the 2040 and 2060 projections found their respective increase of between 1.8 to 2.16 m and 2.04 to 2.28 m (EPU, 2012).

In addition, the comparative analysis of the Highest Astronomical Tide (HAT) (NHC, 2012) for the baseline condition and the projection for the 2060 shows an occurrences of water level differences from 0.01 to 0.51 m (Table 1).

Table 1. Comparison of the Highest Astronomical Tide (HAT) (Source: EPU, 2012)

No	Item	Observed (m)	Forecast (m)	*Difference (m)
1	HAT 1.2	1.58	-	-
2	Model 0.51	-	1.57	0.01
3	Existing condition (current)	-	1.64	-
4	Projection 2020	0.11	1.75	0.11
5	Projection 2040	0.25	1.91	0.27
6	Projection 2060	0.50	1.45	0.51

* Difference between the current forecasts and projection forecasts

Based on the analysis carried out on the numerical modelling results, there is an increase in the wave heights that propagate towards the coastline, in line with the rising sea level and these may cause changes to the current flow pattern. The results of this study is quite reasonable in its degree where the higher the sea level rise, then the distant the waves penetrate onshore will also increase.

Simulation results does not show significant changes on the SLR impacts for the year 2020 and 2040 compared to the baseline condition. However, simulations for 2060 indicates significant changes in terms of wave heights in the study area. Although the risk of the increasing wave heights in Sandakan Town is quite minimal, Pulau Duyong face a higher risk with an increase of 0.18 m.

Hydrodynamic modelling results also indicate that the increase of current speed is proportionate with the increase in SLR, depending on the depth of the seabed. Based on the baseline condition, the average current speed recorded highest in the vicinity of the canal between Pulau Duyong and Sandakan Town i.e. between 0.3 - 0.5 m/s. The coastal areas around Sandakan Town which is protected by Pulau Berhala shows lower current speeds with an average of about 0.1 m/s.

Based on the statistical maximum current speed, the area surrounding the canal between the Sandakan Town and Pulau Duyong experience speeds above 0.9 m/s in the baseline condition; and this value is expected to spread wider to the rest of the canal by the year 2060. When SLR occurs, some beaches with shallow profiles show higher current speeds while other beaches with deeper profiles indicate a reduction in the current speeds.

Comparison between the baseline and the 2020 and 2040 current speeds shows no significant changes. However, comparison between the baseline and 2060 current speeds indicates a maximum increase of 0.15 m/s. Figure 3 shows the modelled current speeds for the baseline condition; current speeds generated by the projected sea level rise for year 2060; and the difference between them.

Table 2 shows the distribution of the Management Unit (MU) for the study area and the analysis of vulnerability and the impact of rising sea level on the Physical, Ecology and Socio-economy aspects in the study area. These Physical, Ecology and Socio-economic Indexes are then combined to produce the Total Vulnerability Index (TVI) as summarised in Figure 4 and Table 3. Some of the adaptation measures often used in addressing rising sea level are increasing the level of the rock revetment; building sea walls, improving the existing structures by installing fence or railing as the sea barriers; reclamation; raising the platform level of the jetty/pier/port; and relocation of residents to a higher ground.

There are also other methods of adaptation, such as building raft houses; floating houses; as well as the construction of houses on stilts or piles. This study has also recommended some suitable adaptation measures with an estimated cost to face the phenomenon of the rising sea levels (until the year 2060) as shown in Tables 4 - 6.

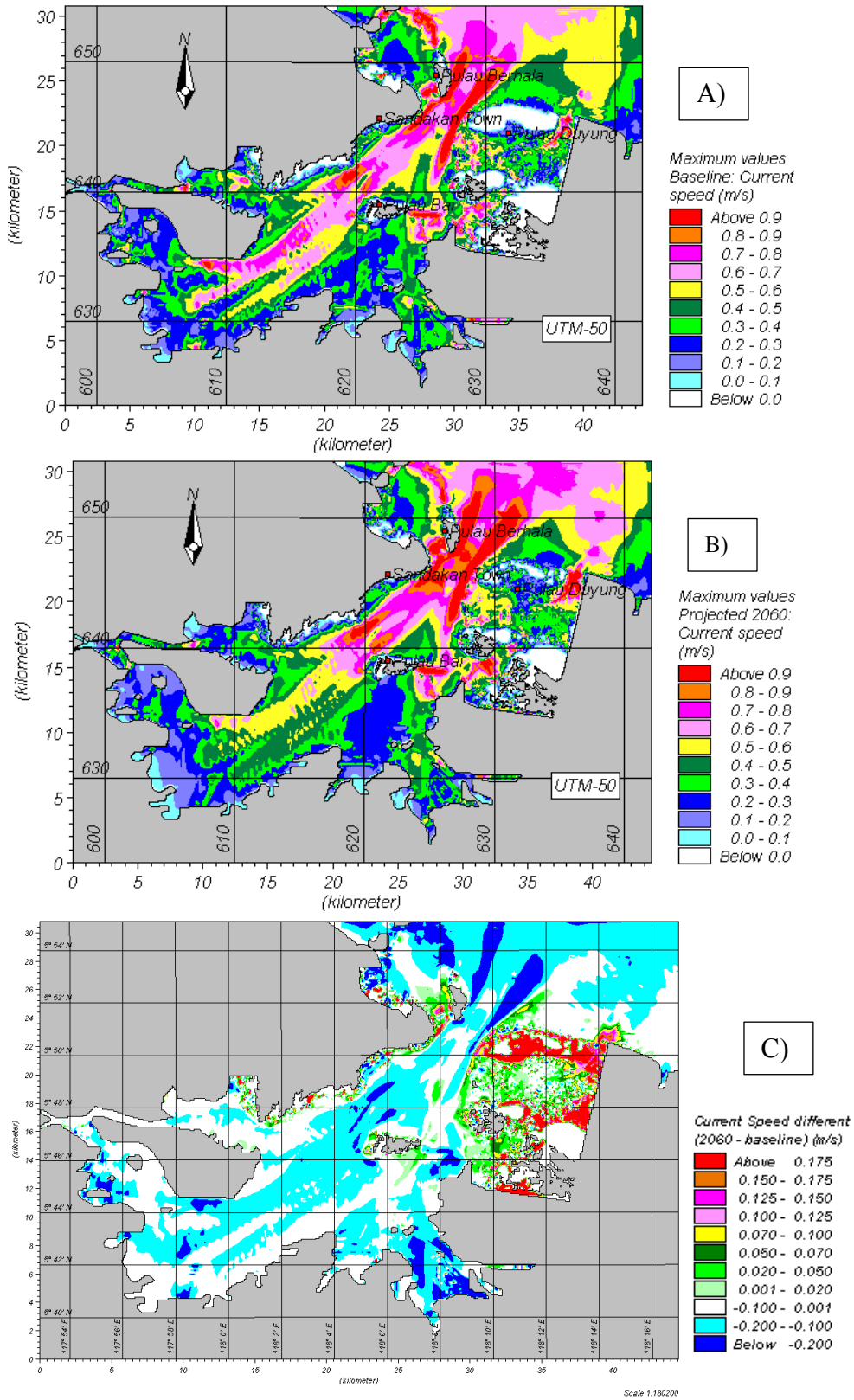

Figure 3. Modelled current speed (m/s): A) Maximum values baseline; B) Maximum values Projected 2060; and C) Difference in current speed (2060 – baseline) (Source: EPU, 2012)

Table 2. Distribution of the Management Units (MU) in the study area and the analysis of their Physical, Ecology and socio-economic aspects (Source: EPU, 2012)

MU	Study area	Physical	Socio-economy	Ecology	Note
1	Sandakan Town (Taman Ramai-Ramai to Custom Office)	Water village - coastal length about 250 m	Majority population – immigrants. Main activity - trading & fisheries	Natural beach	Floating rubbish and sanitation
2	Sandakan Town (Post Office to Library)	Administration buildings and jetty - coastal length about 490 m	Main activity - fisheries	Developed beach (jetty & sea wall)	High platform level and protected by sea wall
3	Sandakan Town (Roundabout beside Post Office to APMM Jetty)	Coastal road and protected by rock revetment – coastal length - 520 m	Trading and commercial area	Developed beach (jetty & sea wall)	Highest platform level and protected by sea wall
4	Sandakan Town (Navy Base to Central Market)	Coastal road and walkway, commercial buildings and protected by rock revetment – coastal length - 390 m	Bustling with economic activities, popular with local and foreign tourist (hotel, shopping mall & restaurants)	Developed beach (jetty & sea wall)	Commercial buildings very close to the sea
5	Sandakan Town (Central Market to Marine Police Complex)	Coastal road, sea front, commercial buildings and jetty – coastal length - 370 m	Commercial, landing area for small boats, passengers, vessels & fishing boats	Developed beach (jetty & sea wall)	Platform level is rather low & almost inundated during high tides
6	Pulau Duyong (northern coast with no population)	Low lying sandy beaches with no development	Fishermen activities from Kampong Tanjung Aru	Common island flora such as *Casuarina equisetifolia*, *Terminalia catappa*, *Cinnamomun sp.* & *Hibiscus tiliaceus*	Subjected to direct propagation of waves during the monsoon season
7	Pulau Duyong (Kampong Tanjung Aru)	Well planned community with impressive houses and school	Fishing & agricultural economic activities	Common island flora, some has been removed to make way for public school for community development	Houses built on stilts
8	Pulau Duyong (southern area with no population)	Muddy beaches with mangrove forest	Fishermen activities from Kampong Tanjung Aru	Mangrove species such as *Rhizophora mucronata; Rhizophora apiculata; Avicennia sp.; Bruguiera sp.* & *Sonneratia sp.*	mudflats and mangrove forests - exposed to coastal erosion

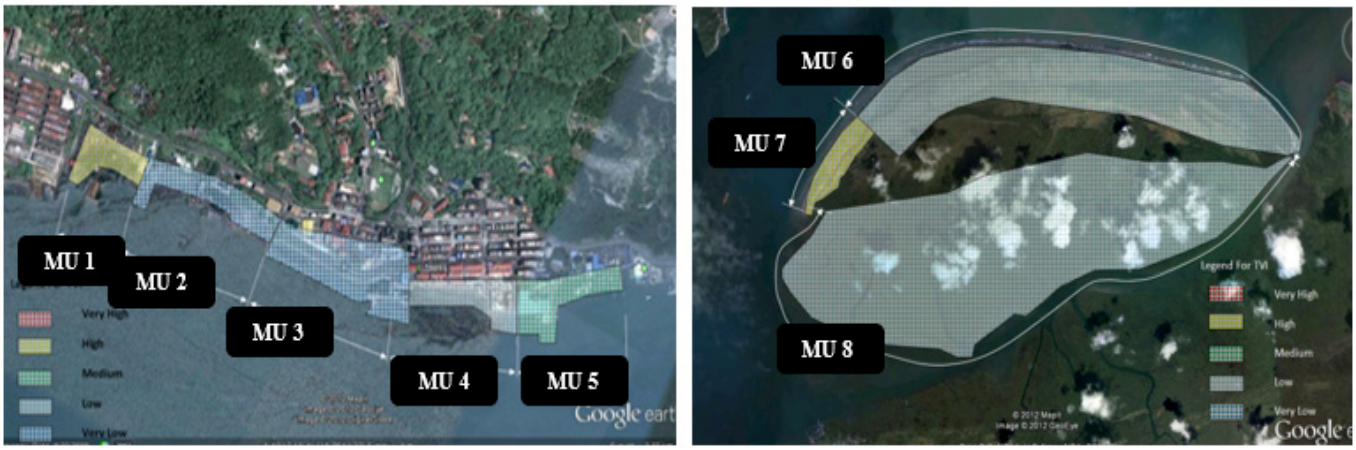

Figure 4. Total Vulnerability Index (TVI) for Sandakan Town (left); and Pulau Duyong (right) (Source: EPU, 2012)

Table 3. Summary of the vulnerability and impacts for each Management Unit (MU) for year 2060 and their adaptation measures for Sandakan coast (Source: EPU, 2012)

MU	Total Vulnerability Index (TVI)	Description	Impacts	Adaptation Measures
1	High	Low lying beach profiles High population at the water villages along the coastline	Inundation is the major problem here Land lost due to inundation is about 0.6 ha	Adaptation measures are incorporated in periodic maintenance by local residence
2	Very low	Coastline is bounded by high vertical wall Comprise of government buildings and amenities i.e. library, custom complex etc.	Freeboard is approximately 0.5 m No damage or land lost occur from SLR due to the high sea wall	None
3	Very low	The coastline is protected by rock revetment Comprises of commercial buildings and Navy base	Freeboard is approximately 0.6 m but varies places to places No damage or loss due to SLR	None
4	Low	The coastline is protected by rock revetment Comprises of commercial buildings and tourist area	No damage or loss due to SLR Freeboard will be reduced from 0.9 m to 0.4 m in year 2060 Reduction in comfort level	Low wall or railling
5	Mederate	The coastline is protected by sea wall Comprises of Market Building and Marine Police Complex	Loading Jetty at the Market Building will be inudated and this jetty has to be rebuilt The freeboard at Marine Police Jetty will be reduced to 0.1 m in the year 2060. The platform levels need to be raised or rebuilt Most of the slipway at Marine Police Jetty will be inundated in year 2060 and this will jeorpodise its operation. Thus the slipway levels need to be raised	Raise platform levels for jetties and slipways
6	Low	The coastal areas is mainly covered by coastal forests No human settlement	Inundation can go as far as 150 m landward, increase in wave heights and current speed is 0.175 m and 0.3 m/s, respectively during the monsoon season Loss of land about 94 ha due to 0.5 m SLR	None

MU	Total Vulnerability Index (TVI)	Description	Impacts	Adaptation Measures
7	High	The coastline is low and flat Consists of picturesque and well organised water village	increase in wave heights and current speed is 0.18 m and 0.15 m/s respectively, may lead to shoreline erosion and steepening of the beach profile Loss of land about 16 ha due to 0.5 m SLR	Rock bund with suitable toe at shoreline
8	Low	The coastal areas is mainly covered by mangroves No human settlement	Loss of about 958 ha of mangrove area due to 0.5 m SLR In monetary terms, this translates to about RM 8.8 million	None

Table 4. Cost estimates for 2020 adaptation measures (Source: EPU, 2012)

MU	Adaptation Measures	Cost / m (RM)	Length	Estimated Cost (RM)
1	None	-	-	-
2	None	-	-	-
3	None	-	-	-
4	None	-	-	-
5	Raise jetty and slipway platform levels			
	Jetty at Market Building	30,000	150	4,500,000
	Jetty at Marine Police Complex	-	-	-
	Slipway at Marine Police Complex	-	-	-
6	None	-	-	-
7	Rock Bund	5,000.00	1000	5,000,000.00
8	None	-	-	-
			Total	9,500,000.00

Table 5. Cost estimates for 2040 adaptation measures (Source: EPU, 2012)

MU	Adaptation Measures	Cost / m (RM)	Length (m)	Estimated Cost (RM)
1	None	-	-	-
2	None	-	-	-
3	None	-	-	-
4	None	-	-	-
5	Raise jetty and slipway platform levels			
	Jetty at Market Building	-	-	-
	Jetty at Marine Police Complex	-	-	-
	Slipway at Marine Police Complex	-	-	-
6	None	-	-	-
7	Rock bund	-	-	-
8	None	-	-	-
			Total	0.00

Table 6. Cost estimates for 2060 adaptation measures (Source: EPU, 2012)

MU	Adaptation Measures	Cost / m (RM)	Length (m)	Estimated Cost (RM)
1	None	-	-	-
2	None	-	-	-
3	Raise jetty platform level	-	-	-
4	Low wall / railing	2,000.00	500	1,000,000.00
5	Raise jetty and slipway platform levels	-	-	-
	Jetty at Market Building			
	Jetty at Marine Police Complex	40,000.00	100	4,000,000.00
	Slipway at Marine Police Complex	50,000.00	75	3,750,000.00
6	None	-	-	-
7	Rock bund	-	-	-
8	None	-	-	-
			Total	8,750,000.00

5 CONCLUSION

The projected SLR in Sandakan has been estimated to be around 0.1 m, 0.25 m and 0.5 m for the year 2020, 2040, and 2060 respectively. These values have been derived from the simulation using the AOGCM models. Hydrodynamic modeling works have shown that these increase in sea levels will result in corresponding change in the nearshore wave and hydrodynamic flow patterns. In general, the hydraulic modeling shows that the wave height at the shoreline tends to increase with the water level, as the higher water levels will allow the waves to penetrate closer to the shoreline. For the year 2020 and 2040 scenarios, the hydrodynamic model results did not show any significant change compared to the existing (baseline) conditions. However, for the 2060 scenario, there will be no change in the wave heights in Sandakan Bay (existing height is about 0.2 m), while that at Pulau Duyong is much larger, an increase of 0.18 m compared to the existing height of 2.6 m.

Similarly, hydrodynamic modeling shows that some of the shoreline and shallower areas tend to experience increase in velocity while some of the deeper areas tend to show a decrease in velocity. Since the tidal flow is still the same, the increase in water levels will create bigger flow area which results in a decrease in velocity. In contrast, for shoreline and shallow areas, as water level increases, there is less frictional effects from the sea bed which results in higher velocity. For the 2060 scenario, the maximum increase in current speed is 0.15 m/s, compared to the current velocities of around 0.3 to 0.5 m/s.

Overall, the impact of the SLR is more pronounced in Pulau Duyong compared to Sandakan Town. This is probably because Sandakan Town is built up on a raised platform level that is relatively safe from the projected SLR for the year 2060. On the other hand, majority of Pulau Duyong which comprise of a low lying area and covered by mangrove forests that grow below the Mean High Water (MHW) mark. It is anticipated that there will be a reduction of about 53% of the existing 1,800 hectares of mangrove forest (about 958 hectares) due to erosion and inundation caused by the rise of 0.5 m sea level in the year 2060. The loss is estimated to be around RM8.8 million.

Some adaptation measures have been proposed to minimise the impact of SLR in the study area, such as the construction of low walls or railings to give comfort to the pedestrians around Sandakan Town (in MU 4). It is also recommended that the existing jetties and slipways near the Market Buildings and Marine Police Jetty (in MU 5) to be raised to a higher level to avoid flooding. Construction of dykes and revetment was proposed in Kampung Air, Pulau Duyong (in MU 7) to protect the area from waves and currents action. Overall, the total cost of adaptation involved is estimated to be about RM 18.25 million.

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