SEA LEVEL RISE IN MALAYSIA

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Although the global prediction for sea level rise is about 1.7 – 3.1 mm/year, the regional sea level rise in Malaysia is expected to be higher, owing to local climate and topographical conditions. Low-lying areas with high population and socio-economic activities are at risk of being inundated. Malaysia has a long shoreline with most of the cities located near the coast, and NAHRIM has carried out a number of studies as our preparation to face global warming issues in terms of projections for sea level rise in Malaysia, and production of Potential Sea Level Rise (SLR) Inundation Maps and Coastal Vulnerability Assessments for high risk areas. These Potential SLR Inundation Maps can be used as a guide for planning and implementation agencies such as theDepartment of Town and Country Planning (JPBD), the Drainage and Irrigation Department (DID), the Public Works Department (PWD) and Local Authorities in their development and adaptation planning, avoiding massive development in critical areas.

Introduction

Until quite recently, climate change and global warming were foreign words to us. However, thanks to climate change scientists from all over the world and their research findings, some of us are now more aware that global daily temperature is increasing (Karl *et al*, 1991), and these phenomena are believed to be the reason why natural disasters such as floods, droughts, landslides, hurricanes and storm surges are more frequent than previously. The International Panel on Climate Change (IPCC, 1995) reported that the global mean surface air temperature has increased by 0.5°C in the 20th century and is projected to increase further in this century, i.e. between 1.5 to 4.5°C. These temperature changes will have many negative effects, including greater frequency of heat waves; increased intensity of rain events and storms, floods and droughts; rising sea levels; a more rapid spread of disease; rising number of natural disasters and casualties due to landslides and loss of biodiversity (McLean, 2009).

Rising sea levels also pose a particular threat to countries with high population and socio-economic activities in the coastal regions. Church *et al*. (2001) predicted a sea level rise (SLR) of 0-1 meter during the 21st century.

According to Dasgupta *et al*. (2007), three main factors contributing to the rising seas are: ocean thermal expansion; melting of the Greenland and Antarctica glacier and ice sheets; and changes in terrestrial storage, with ocean thermal expansion as the dominant factor. However, new data on rates of deglaciation in Greenland and Antarctica suggest greater significance for glacial melt, and a possible revision of the upper-bound estimate for SLR in this century. Since the Greenland and Antarctic ice sheets contain enough water to raise the sea level by almost 70 m, small changes in their volume would have a significant effect (Dasgupta *et al*., 2007).

Bindoff *et al*. (2007) estimates the global mean sea level rise rate to be 1.8 ± 0.5 mm/yr for the period of 1961-2003, and 1.7 ± 0.5 mm/yr over the 20th century while Casenave and Nerem (2004) estimate the rate of sea level rise as 3.1 ± 0.7 mm/yr, based on satellite altimetry observations for the period of 1993 to 2003. Large variations in sea level rise were observed in the western Pacific and eastern Indian Ocean, mainly due to ocean circulation changes

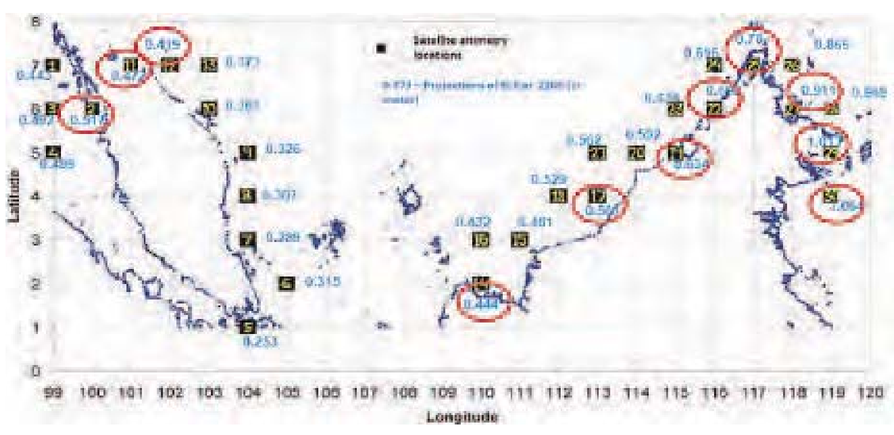

Figure 1: Projected mean sea level rise along the coast of Malaysia for year 2100. Red circles indicate values higher than 0.4 m rise (Source: NAHRIM, 2010).

Station No.	Location	Latitude	Longitude	SLR Rate (mm/year)
1	Sempadan Malaysia (Perlis) - Thailand	6	100	6.08
2	Sempadan P.Pinang – Perak Border	5	99	6.45
3	Perairan Laut Andaman	1	104	3.87
4	Perairan Selat Melaka	2	105	3.68
5	Selat Johor	3	104	2.88
6	Perairan Mersing	4	104	2.73
7	Pulau Tioman	5	104	2.78
8	Persisiran Pantai Pekan	6	103	3.46
9	Cherating	7	103	3.49
10	Pulau Perhentian, Terengganu	7	102	4.29
11	Sempadan Malaysia (Kelantan) - Thailand	7	101	5.20
12	Perairan Tumpat	6	99	5.70
13	Perairan Kelantan	7	99	5.02
14	Perairan Kuching dan Bau	4	113	4.74
15	Perairan Sejingkat (Sibu)	2	110	4.00
16	Perairan Sibu	5	115	5.37
17	Perairan Miri	6	116	5.23
18	Perairan Bintulu	7	117	5.06
19	Perairan Brunei	6	118	5.57
20	Luar Persisir Sabah - Sarawak - Brunei	5	119	6.28
21	Luar Persisir Sabah - Sarawak - Brunei	4	119	7.00
22	Persisiran Pantai Kota Kinabalu	7	118	5.25
23	Pulau Labuan	6	119	5.64
24	Persisiran Pantai Tuaran - Kota Belud	7	116	5.17
25	Teluk Marudu, Kota Marudu - Kudat	6	115	5.27
26	Perairan Pitas	5	114	5.11
27	Perairan Sandakan	5	113	4.84
28	Laut Sulu	4	112	4.51
29	Perairan Lahad Datu	3	111	4.13
30	Perairan Tawau	3	110	3.82

associated with El Niño–Southern Oscillation or El Niño/La Niña–Southern Oscillation (ENSO) events (Church et al., 2006).

Sea level change varies spatially with some regions showing higher rates compared to the global mean sea level rise while sea level in other regions is falling, probably due to regional thermal expansion (Cazenave and Nerem, 2004). The increase in occurrences of extreme high water due to storm surges and variations in the extremes related to mean sea level rise in the regional climate are also evident (Bindoff *et al*., 2007).

Projection of Sea Level Rise in Malaysia

The Study of the Impact of Climate Change on Sea Level Rise in Malaysia (NAHRIM, 2010) was carried out in 2010, to project SLR in the Malaysian coast for the year 2100. Using linear trend analysis, satellite altimetry data (1993 – 2010) from 30 stations around Malaysia (Figure 1) were analysed to obtain the rate of SLR for Malaysia. These values were then assimilated with the results from 49 simulations of 7 Coupled Atmospheric-Oceanic General Circulation Model (AOCGM) for SLR projections along the coast of Malaysia (NAHRIM, 2010). The results showed that:

(i) There is a significant increase in SLR trend over the recent 5 years, compared to the SLR trend over 20 years ago;
(ii) The observed Mean SLR rate along the Malaysian coast (based on satellite altimetry data from 1993 – 2010) is between 2.7 – 7.0 mm/yr.;
(iii) In Peninsular Malaysia, the projected SLR for the year 2100 is 0.25 – 0.5 m with the maximum value occurring in low-lying areas along the Northeast and West coast of the peninsular (Kelantan and Kedah);
(iv) In Sabah, the projected SLR for the year 2100 is 0.69 – 1.06 m with the maximum value occurring in low-lying areas, river mouths and estuaries in the East coast (Tawau, Semporna, Lahad Datu, Sandakan and Kudat); and
(v) In Sarawak, the projected SLR for the year 2100 is 0.43 – 0.64 m with maximum value occur in low lying areas, river mouths and estuaries in the Southwest coast (Meradong, located between Batang Igan and Batang Rajang).

Table 1 shows the rates of SLR along the coast of Malaysia based on observed satellite altimetry data from 1993 – 2010 while Figure 1 shows the projected mean sea level rise for the Malaysian coast in the year 2100.

Impacts and Adaptation Measures

Climate change and sea level rise can give rise to high impacts such as destruction of assets and disruption to economic sectors, loss of human lives, mental health effects, or loss on plants, animals, and ecosystem and their severity depends on their extremes, exposure and vulnerability (IPCC, 2012; McLean, 2009). Sea level rise may reduce the size of an island or state and its' infrastructure i.e. airports, roads, and capital cities, which normally predominate in the coastal areas; worsen inundation, erosion, and other coastal hazards; threaten vital infrastructure, settlements, and facilities; and thus compromise the socio-economic well-being of the island communities and states (Handmer *et al*., 2012)

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The magnitude of tropical cyclones often governs the magnitude of damage due to storm surge (Xiao and Xiao, 2010). Suzuki (2009) projected the changes in storm surge and associated damage for three major bays in Japan, namely Tokyo, Ise, and Osaka, based on the calculation of inundations for different sea levels and different strengths of typhoons, using a spatial model with information on topography and levees. His results indicate that a typhoon with the strength of 1.3 times higher than the design standard, combined with a 60 cm sea level rise in the investigated bays will cause damage of about USD 3, 40, and 27 billion, respectively.

Warming of the ocean surface will give impacts to the biodiversity and the growth rates of species that are sensitive to temperature such as corals (Handmer *et al*., 2012). They reported that damage to structures, infrastructure, and crops during tropical cyclones and water shortage are the main impacts from climatic extremes in the tropical regions. On atolls, storm surges, high wave events and 'king' tides would bring a serious problem of salinisation of the freshwater. Therefore, awareness, improved governance, proper development and preparedness are very important in coping with climate change impacts in developing countries (Handmer *et al*., 2012).

Although risks cannot be fully eliminated, disaster risk management and adaptation to climate change are very important to reduce exposure and vulnerability, and increase resilience to the potential adverse impacts of climate extremes (IPCC, 2012). Furthermore, adaptation and mitigation will complement each other hence reducing the risks of climate change significantly (IPCC, 2012). Some of the alternative methods recommended by the Malaysian Drainage and Irrigation Department's Manual (DID Manual, 2009) to mitigate the damage of coastal storms and forces are accommodation, protection, beach nourishment, retreat; do-nothing; integrated shoreline management plan, and refurbishment on coastal bund.

Based on the SLR Projections mentioned earlier, NAHRIM then carried out Desktop Studies on four (4) selected high risk areas along the coast of Malaysia, i.e. Kedah Estuary, Terengganu Estuary, Kota Kinabalu, Sabah and Sarawak Estuary. Using Numerical Modeling Suite and GIS Software, Potential SLR Inundation Maps were produced to assess the impact of SLR towards the population, development and the road systems that exist within these areas.

Figure 2 shows Potential SLR Inundation Maps for Kedah Estuary. These Potential SLR Inundation Maps may be used as guides for planning and implementation agencies such as the Town and Country Planning Department, the Drainage and Irrigation Department, the Public Works Department and Local Authorities in their development and adaptation planning; minimising massive development in critical area, hence reduce the impact of SLR towards the country's population and it's socio-economics well-being (Nor Aslinda *et al*., 2012).

Way Forward

SLR has the potential to change coastal natural processes, marine habitats and ecosystems, which will affect the infrastructure and thence the socio-economy of Malaysia. These impacts or disasters may be minimized or avoided with knowledge and preparedness.

Since the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) is now underway and is expected to be finalized in 2014, NAHRIM intend to revise the existing SLR Projections along the coast of Malaysia, based on the new findings of AR5.

A lot of detailed studies will have to be undertaken in Malaysia on climate change and sea level rise related issues such as the potential inundation maps for sea level rise in other critical locations throughout Malaysia, vulnerability index for sensitive areas, assessment of potential impacts of climate change on other vulnerable sectors such as agriculture, forestry, biodiversity, water resources, coastal and marine resources, public health and energy. The findings from these studies will be incorporated into existing or new policies so that all development or infrastructure planning and activities will be implemented in a sustainable manner with less disaster risks towards the human population.

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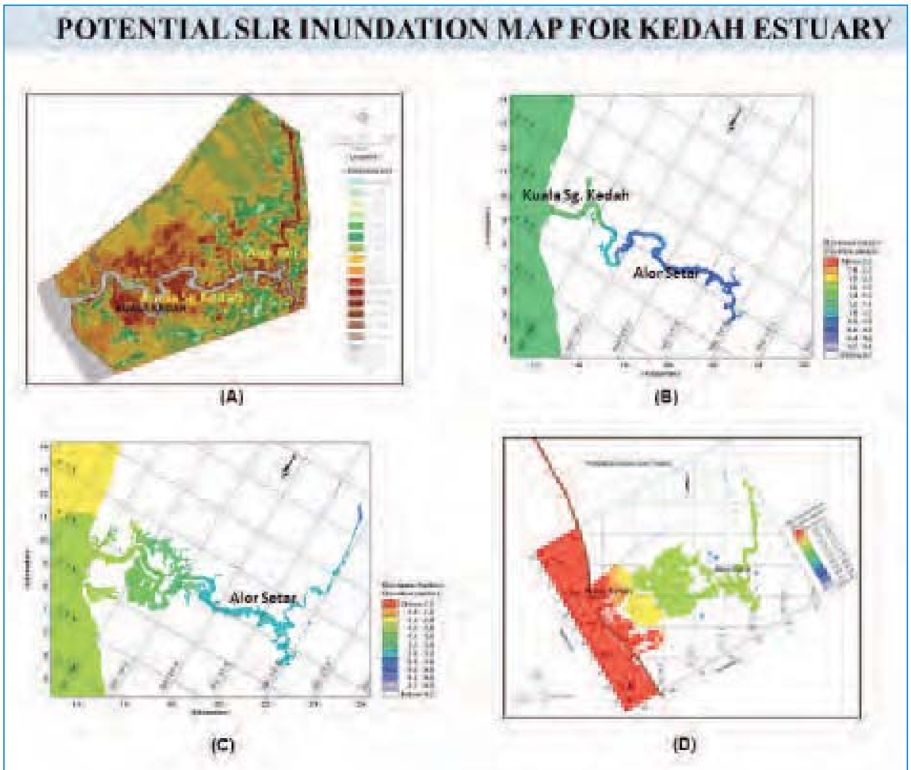

Figure 2: (A) Existing Topography of Kedah Estuary study area of 70 km2;
(B) Existing SLR Inundation Map (0 m);
(C) Potential Inundation Map with 0.5 m SLR; and
(D) Potential Inundation Map with 1.0 m SLR (Source: Nor Aslinda et al., 2011)