IMPACT OF CLIMATE CHANGE TO SEA LEVEL RISE IN MALAYSIA

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Bilik Gerakan,
NAHRIM

Coastal & Oceanography Research Centre
NAHRIM

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IMPACT OF CLIMATE CHANGE TO SEA LEVEL RISE IN MALAYSIA

Overview
Studies and Reports
Vulnerability & Adaptation
Adaptation Measures
Conclusion & Way Forward

About Malaysia…

Geography of Malaysia	
Continent	Asia
Region	Southeast Asia
Coordinates	2°30'N 112°30'E
Area	
• Total	330,803 km^2 (127,724 sq mi)
• Land	99.63%
• Water	0.37%
Coastline	4,809 km

- **In 2016, total population of Malaysia is estimated at 31.7 million persons.**
- **The average rainfall is 250 centimeters a year**
- **The average temperature is 27 °C (80.6 °F).**

- **Located near the equator, Malaysia's climate is categorized as equatorial, being hot and humid throughout the year.**

OBSERVED CLIMATE CHANGE

MALAYSIA

- Rate of warming (temperature): 1969-2009#
  - 1.1°C/50-yr - Semenanjung Malaysia;
  - 0.6°C/50-yr - Sarawak;
  - 1.2°C/50-yr - Sabah;
- 1-hr & 3-hr short duration rainfall intensity in 2000-2007 increased 17% & 29% respectively compared to 1970s
- Sea level rise (satellite altimetry) – 2.73 – 7.00 mm/year (1993 to 2010)

#Source: Malaysia Meteorology Department

GLOBAL

- Rate of warming (temperature): (AR5, IPCC) - 1901-2012: 0.89 °C [0.69 to 1.08] °C
- Global average sea level rise (AR5, IPCC) – 1901-2010: 190 [170 to 210] mm

Kampong Permata, Pontian, Johor

Regional sea level rise by the end of the 21st century

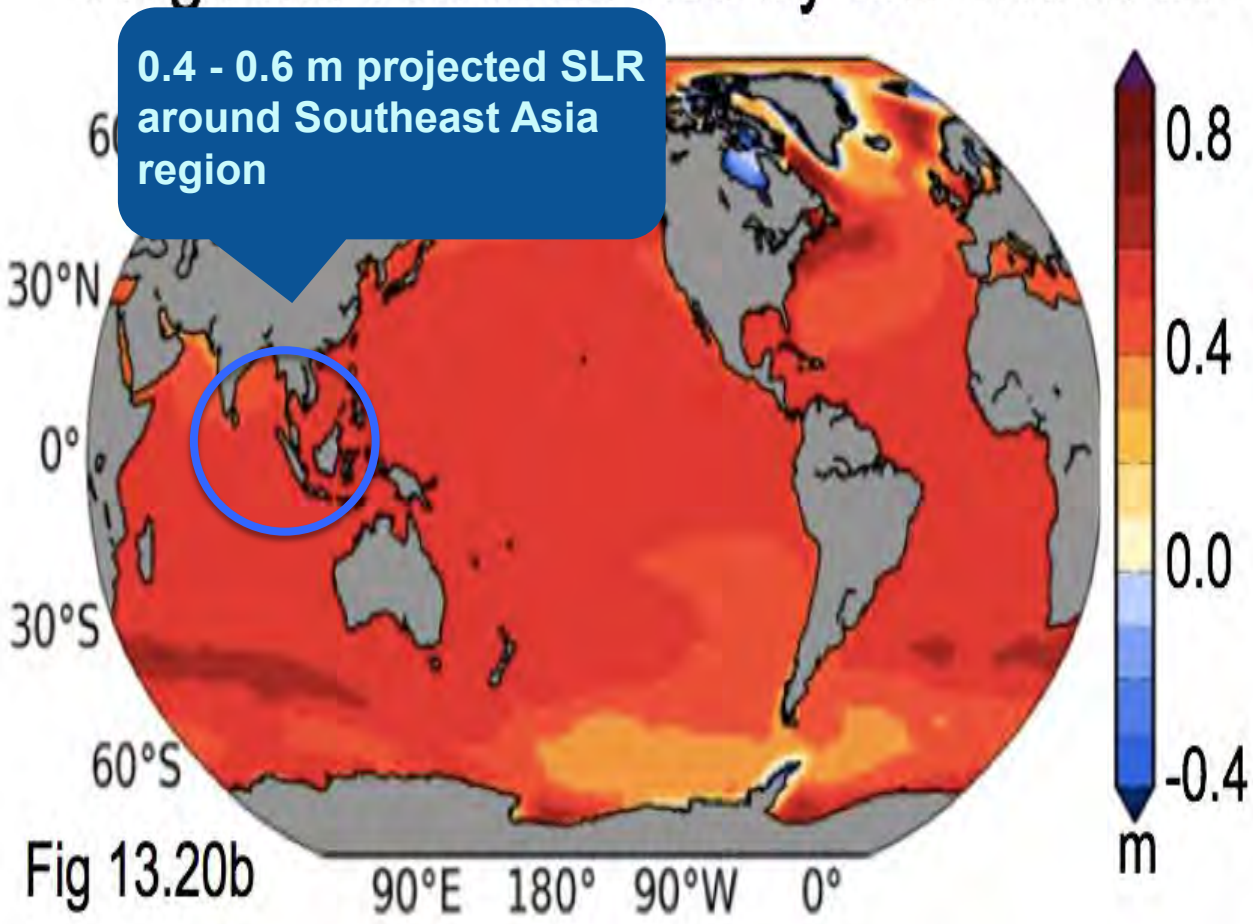

Fig 13.20b

It is *very likely* that sea level will rise in more than about 95% of the ocean area.

IPCC 2013 Fig 13.20b

Source: Prof. Dr Fredolin Tangang, January2014

- Three main factors contributing to the rising seas are (Dasgupta *et al*., 2007):
  - ocean thermal expansion;
  - melting of the Greenland and Antarctica glacier and ice sheets; and
  - change in terrestrial storage, and the most dominating factor is the ocean thermal expansion.

How

Future Climate Change :

Malaysia & Southeast Asia region

- Warmer temperature ✓
- More intense precipitation events ✓
- Large variations of rainfall and temperature associated with ENSO ✓
- Changes in monsoon ✓
- **Sea level rise** ✓
- Warmer ocean & acidification ✓

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Source: Prof. Dr Fredolin Tangang, January2014

SUMMARY OF PROJECTED CLIMATE CHANGE

Climate Parameter	Peninsular Malaysia [RegHCM-PM]	Sabah [RegHCM-SS]	Sarawak [RegHCM-SS]	World [IPCC AR4]
Annual mean surface temp.	[2050] 1.0-1.5°C [2100] 2.52-2.95°C	[2050] 1.3-1.7°C [2100] 2.9–3.5°C	[2050] 1.0-1.5°C [2100] 3.0-3.3°C	[2100] 1.7 - 4.4°C
Max. Monthly Rainfall	[2050] +113mm(12%)	[2050] +59mm (5.1%) [2100] +111mm (9%)	[2050] +150mm (8%) [2100] +282mm (32%)	-
Sea Level Rise	0.25-0.52m [2100]	0.64-1.03m [2100]	0.43-0.63m [2100]	0.18-0.59m [2100]

SEA LEVEL RISE IN MALAYSIA

The Study of the Impact of Climate Change on Sea Level Rise on Peninsular Malaysia, Sabah and Sarawak 2010

- Objective : Projections of SLR for Malaysian coast for 2100, based on:-
  - JUPEM Tide gauge data;
  - Satellite altimeter data; and
  - Projections from Global Climate Model (GCM);
- Methodology:
  - *Linear Trend Analysis* on Tide gauge & Satellite Altimeter data – to obtain SLR rates.
  - Assimilation of mean SLR rate with results of 49 simulation of 7 AOGCM Models at satellite altimeter locations available along Malaysian coastlines.

Results from SLR Study 2010

Source: NAHRIM (2010).

SLR Rates (mm/year)

	Malaysia	Global
Tide gauge	0.2 – 4.4 (1984-2010)	1.2 – 2.2 *
Satellite Altimetry	2.73 – 7.0 (1993-2010)	2.4 - 3.8 *

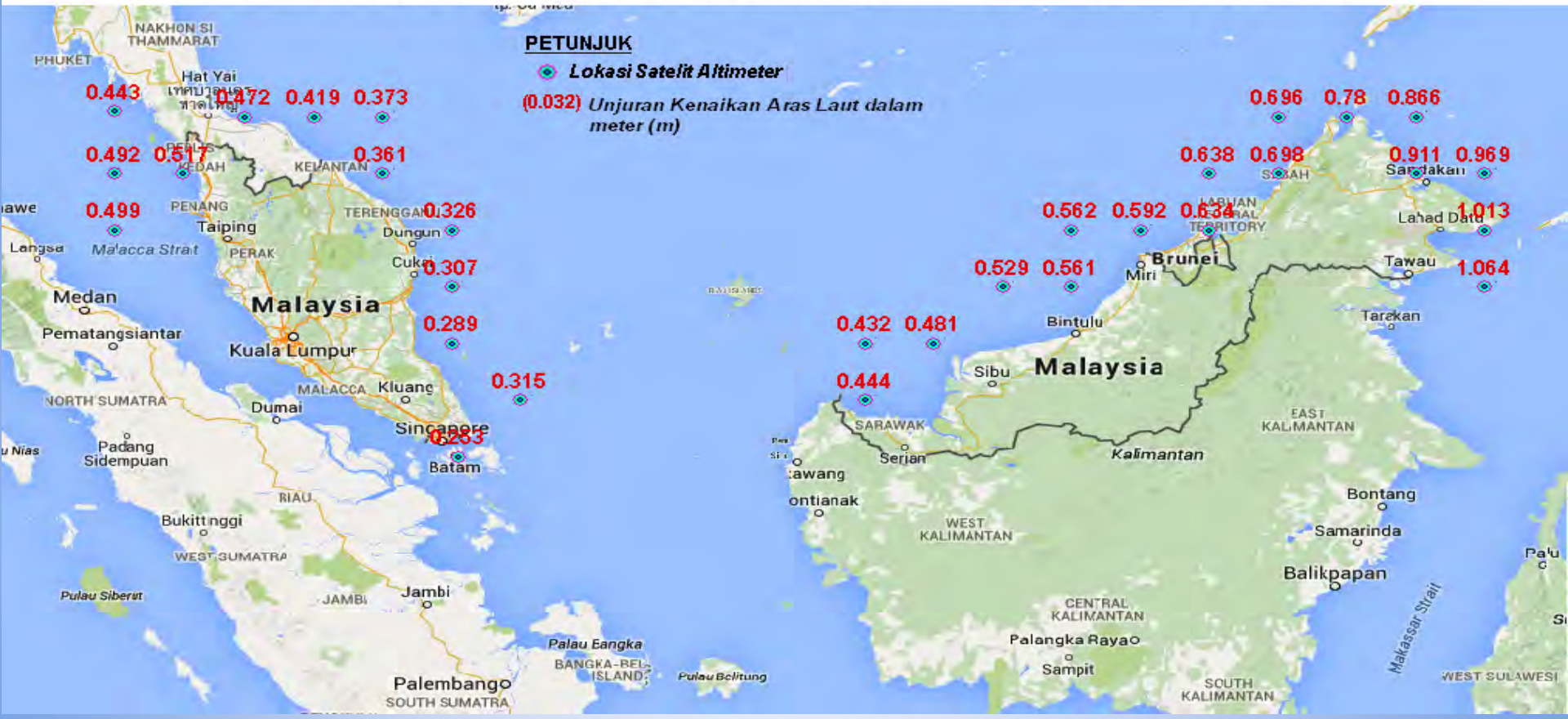
* IPCC (AR4 2007)

Projection on SLR at 2100 for Malaysia

	Sea Level Rise	Note
Projection 2100 (Peninsular Malaysia)	0.25m – 0.52m (2.5 - 5.2 mm/yr)	Maximum SLR – Northeast and West coast of Peninsular Malaysia (Kelantan & Kedah)
Projection 2100 (Sabah & Sarawak)	0.43m – 1.06m (4.3 – 10.6 mm/yr)	1. Maximum SLR– North & East coast of Sabah. 2. Inundation at low lying area and rivermouth/estuaries in Southwest coast of Sarawak (Meradong, located between Batang Igan & Batang Rajang). 3. Inundation at low lying area and rivermouth/estuaries in East coast of Sabah (Tawau, Semporna, Lahad Datu, Sandakan & Kudat).

Projected SLR Study for 2100

Unjuran Kenaikan Aras Laut Purata Pada Lokasi Satelit Altimeter Di Pesisiran Pantai Malaysia Bagi Tahun 2100



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Study of Sea Level Rise Projections for Malaysia 2017

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Study of Impact of Climate Change on Sea Level Rise in Malaysia
(NAHRIM, 2017)

- This study was conducted in collaboration with NAHRIM, Universiti Kebangsaan Malaysia (UKM) & Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia.
- Objective : Projections of SLR for Malaysian coast for 2100, based on AR5 from IPCC :-
  - JUPEM Tide gauge data;
  - Satellite altimeter data; and
  - Projections from Global Climate Model (GCM) & Coupled Model Intercomparison Project Phase 5(CMIP 5)
- Methodology: The projections were derived from Coupled Model Intercomparison Project Phase 5 (CMIP5) combining with data of global ocean thermal expansion, mass loss due to glaciers, surface mass balance of the Greenland and Antartic ice sheets, dynamic response of the ice sheets and land water storage change, and GIA – induced regional sea-level changes associated with changes in surface loading over the last glacial cycle; all of these factors contributed to the regional sea-level differences.
- This latest study of Sea Level Rise Projections for Malaysia was completed on September 2017.

Sea Level Rise Projections in Malaysia - 2017

SLR Rates (mm/year)

	Malaysia	Global
Tide gauge	2.2 - 5.3 (1993 - 2015)	3.2 [2.8 to 3.6]
Satellite Altimetry	2.8 - 4.4 (1993 - 2015)	

* IPCC (AR5 2013)

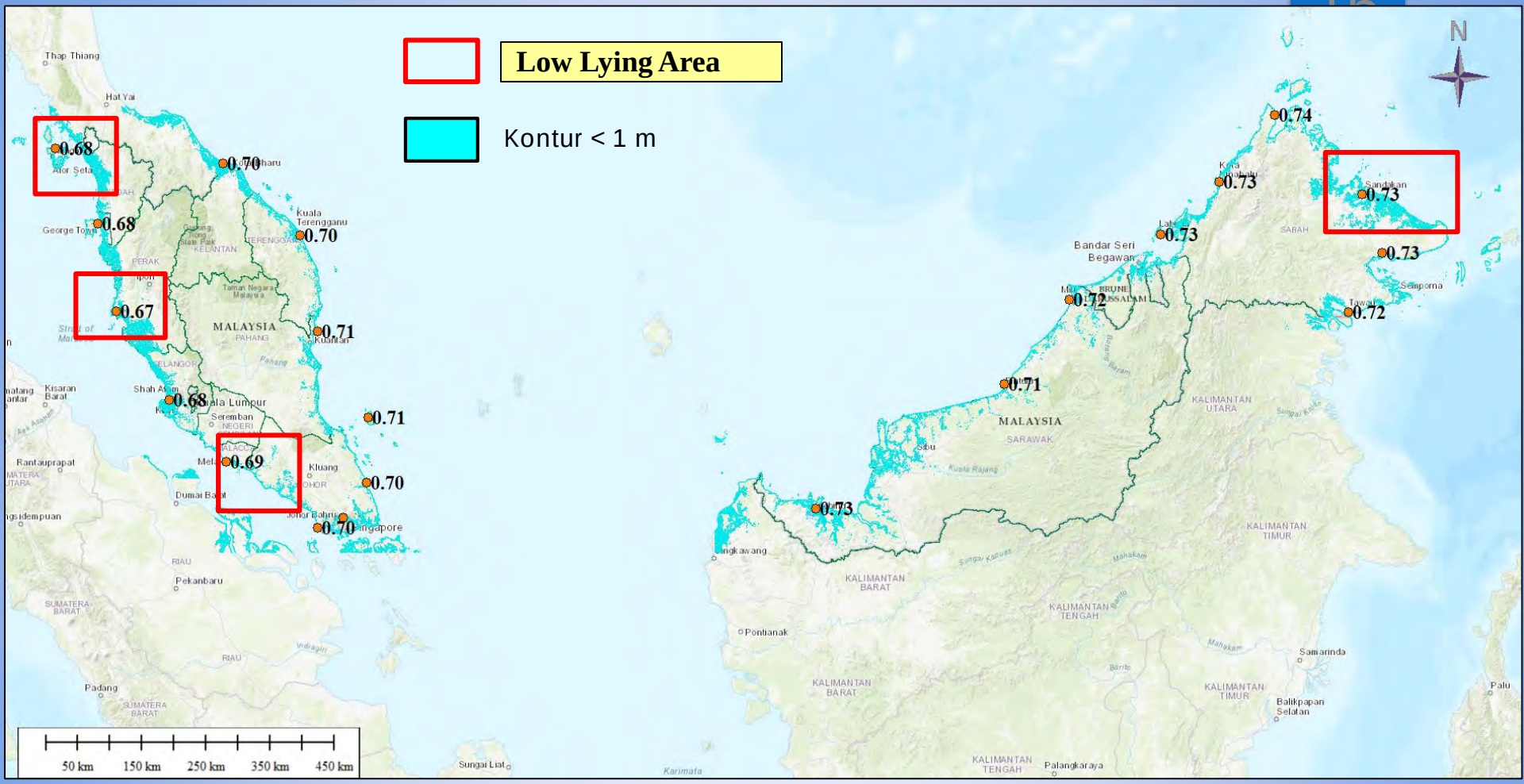
Projection on SLR at 2100 for Malaysia (RCP 8.5)

RCP- Representative Carbon Pathway

	Sea Level Rise	Note
Projection 2100 (RCP 8.5) (Peninsular Malaysia)	0.67 m - 0.71 m (10.5 - 10.9 mm/year)	Maximum SLR – East coast of Peninsular Malaysia (Johor, Pahang, Terengganu & Kelantan)
Projection 2100 (RCP 8.5) (Sabah & Sarawak)	0.71m - 0.74m 10.9 - 11.1mm/year)	1. Maximum SLR– Sabah (Kudat)

* Global Projection for AR5 RCP 8.5 - 2100 is 0.73 (0.52 - 0.98)m with rate of (8 -16 mm/year)

Projected SLR Study for 2100



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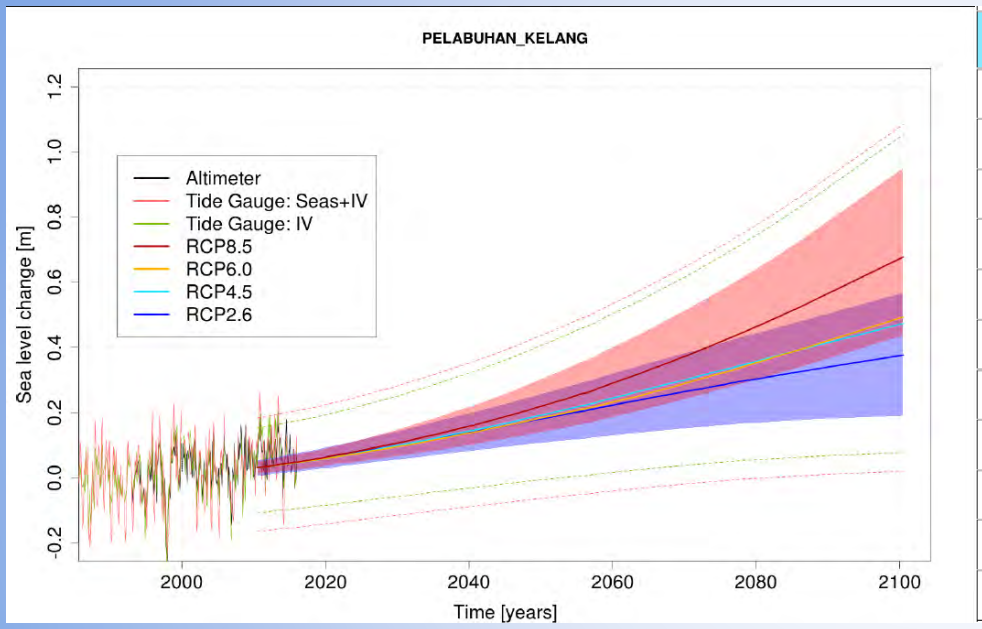
Sea Level Rise Projections : Pelabuhan Klang



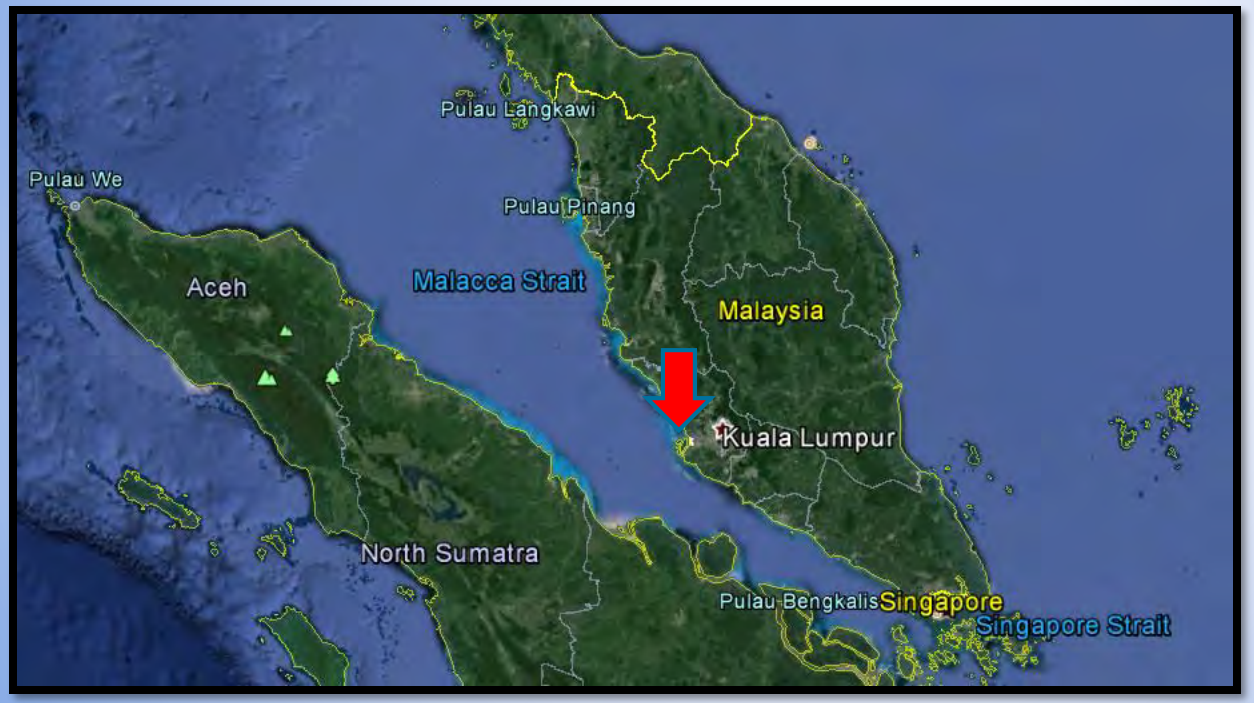
Year	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
2020	0.06 [0.03 - 0.10]	0.06 [0.03 - 0.09]	0.06 [0.03 - 0.09]	0.07 [0.04 - 0.09]
2030	0.10 [0.06 - 0.14]	0.10 [0.06 - 0.14]	0.10 [0.05 - 0.14]	0.11 [0.07 - 0.15]
2040	0.14 [0.08 - 0.20]	0.15 [0.09 - 0.20]	0.14 [0.08 - 0.20]	0.16 [0.10 - 0.22]
2050	0.18 [0.11 - 0.26]	0.19 [0.12 - 0.27]	0.19 [0.11 - 0.26]	0.22 [0.14 - 0.31]
2060	0.22 [0.13 - 0.32]	0.25 [0.15 - 0.35]	0.23 [0.14 - 0.33]	0.29 [0.19 - 0.41]
2070	0.27 [0.15 - 0.39]	0.30 [0.18 - 0.43]	0.29 [0.17 - 0.41]	0.38 [0.24 - 0.52]
2080	0.30 [0.17 - 0.45]	0.36 [0.22 - 0.51]	0.36 [0.21 - 0.50]	0.47 [0.30 - 0.65]
2090	0.34 [0.18 - 0.51]	0.42 [0.25 - 0.60]	0.42 [0.26 - 0.60]	0.57 [0.37 - 0.80]
2100	0.38 [0.19 - 0.57]	0.47 [0.28 - 0.68]	0.49 [0.30 - 0.70]	0.68 [0.44 - 0.95]
2081 - 2100	3.6 [1.0 - 6.1]	5.6 [2.9 - 8.5]	6.9 [4.1 - 9.9]	10.6 [6.7 - 15.3]

IMPACTS OF SEA LEVEL RISE

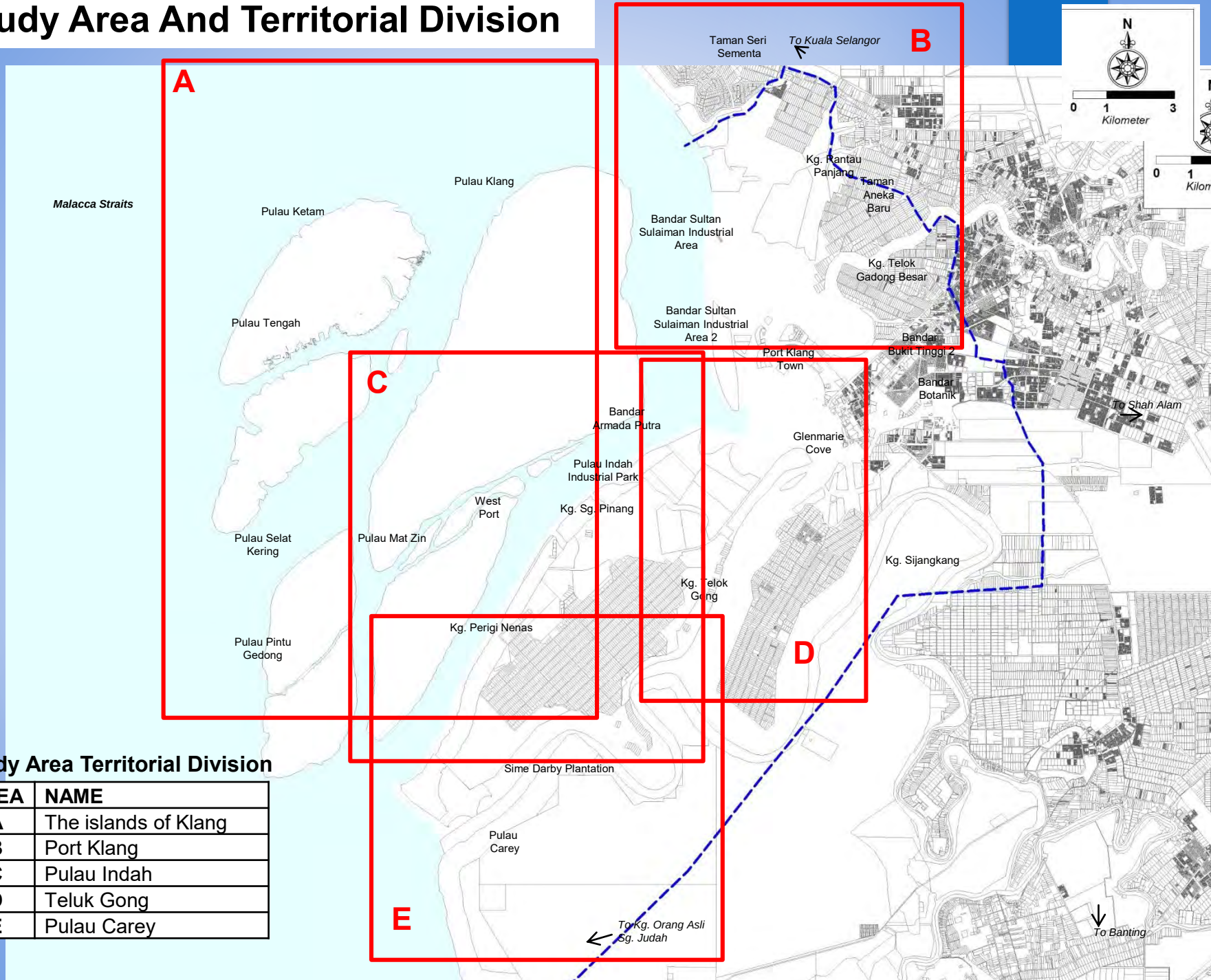
- Combination of extreme events and sea level rise (Mclean, 2009) can cause:-
  - Increased levels of inundation and storm flooding
  - Accelerate coastal erosion and damaged to infrastructures
  - Sea water intrusion
  - Increased loss of property and coastal habitats
  - Increased disease risks
  - Adverse impacts on agriculture, aquaculture, water quality, socio-economy etc.




CASE STUDY: KLANG PORT SEA LEVEL RISE STUDY AREA AND BACKGROUND DATA



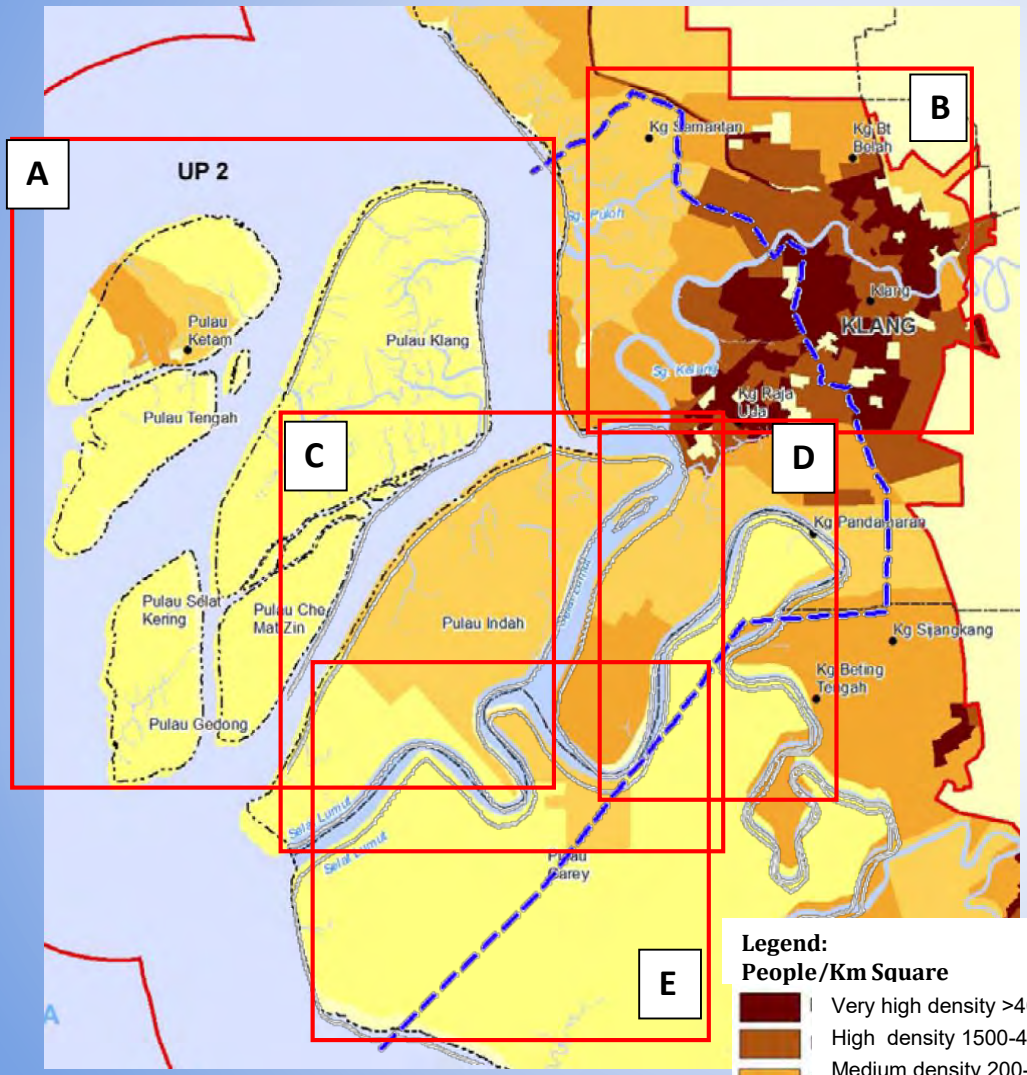
Study Area And Territorial Division



Study Area Territorial Division

AREA	NAME
A	The islands of Klang
B	Port Klang
C	Pulau Indah
D	Teluk Gong
E	Pulau Carey

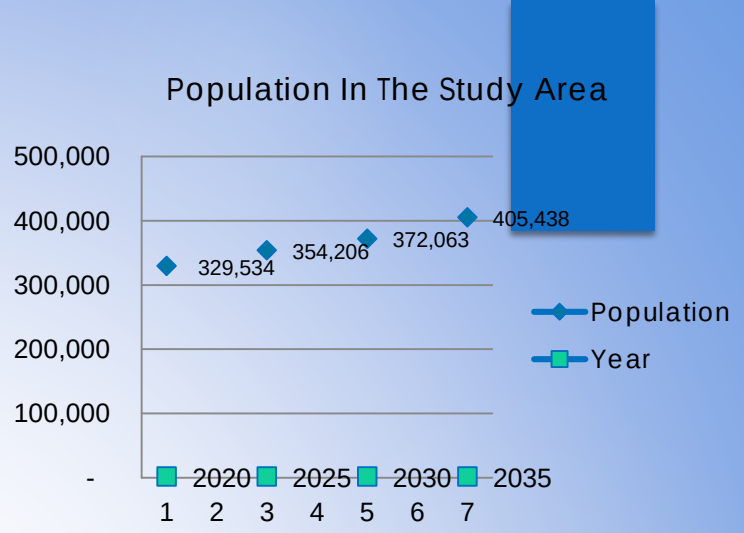
Population and Density (people per km^2).



Legend:
People/Km Square

- Very high density >4000 pax/km sq.
- High density 1500-4000 pax/km sq.
- Medium density 200-1500 pax/km sq
- Low density 50-200 Pax/Km sq.
- Very low density <50 pax/km sq.

Source: NPP-CZ 2012.



Population Density By Area of Study

AREA	NAME	DENSITY (people per km^2).
A	The islands of Klang	Generally most islands are with very low density that is **<50 pax/km sq.** except for Pulau Ketam (low and medium density **200-1500 pax/km sq**)
B	Port Klang	High **1500-4000 pax/km sq**. and very high **>4000 pax/km sq.** density around Port Klang and between Port Klang and Klang Town. Medium and low density on areas north of Sg. Klang
C	Pulau Indah	Very low **<50 pax/km sq.** and low density **50-200 pax/km sq.** around Pulau Indah. Very low density are undeveloped/agriculture areas of the Island
D	Teluk Gong	Medium density **200-1500 pax/km sq** for the villages area and low density **50-200 pax/km sq.** for the Teluk Gong Industrial Area
E	Pulau Carey	Very low density **<50 pax/km sq.**

PROJECTED SEA LEVEL RISE SCENARIO 2012-2100

Projected Year	2020	2040	2060	2080	2100
Meter (m)	0.057	0.134	0.238	0.358	0.495

SLR ASSESMENT BY AREA
AREA A : THE ISLANDS OF KLANG

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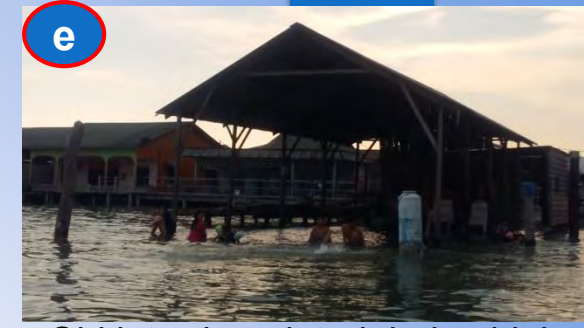
Area A : The Islands of Klang - Existing Condition

Inner section of the waterways

Mangroves threatened by siltation and SLR at Pulau Klang. Projected water level marked by the Forestry Department

High tide water level at Pulau Klang

Low tide water level at Pulau Klang – boat route



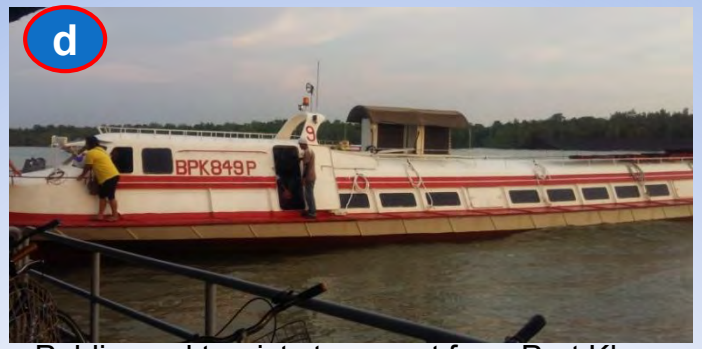
Old jetty, inundated during high tide

The boardwalks and small jetties

Pulau Ketam Jetty during low tide

Area A : Klang Islands – Settlement in Pulau Ketam

Some public facilities be affected by SLR



Public and tourists transport from Port Klang

Commercial activities in the town centre

Tourist accomodation near jetty

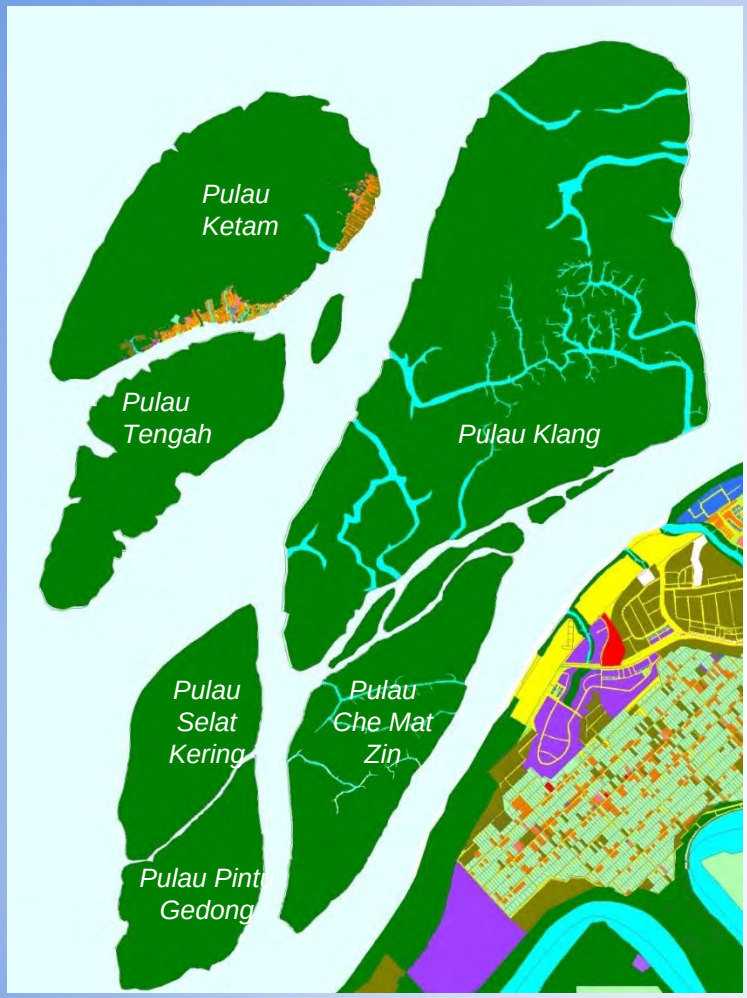
Aquacutures activities near the island coast

Current public utilities runs under the settlement platform

Houses on stilt and private jetties

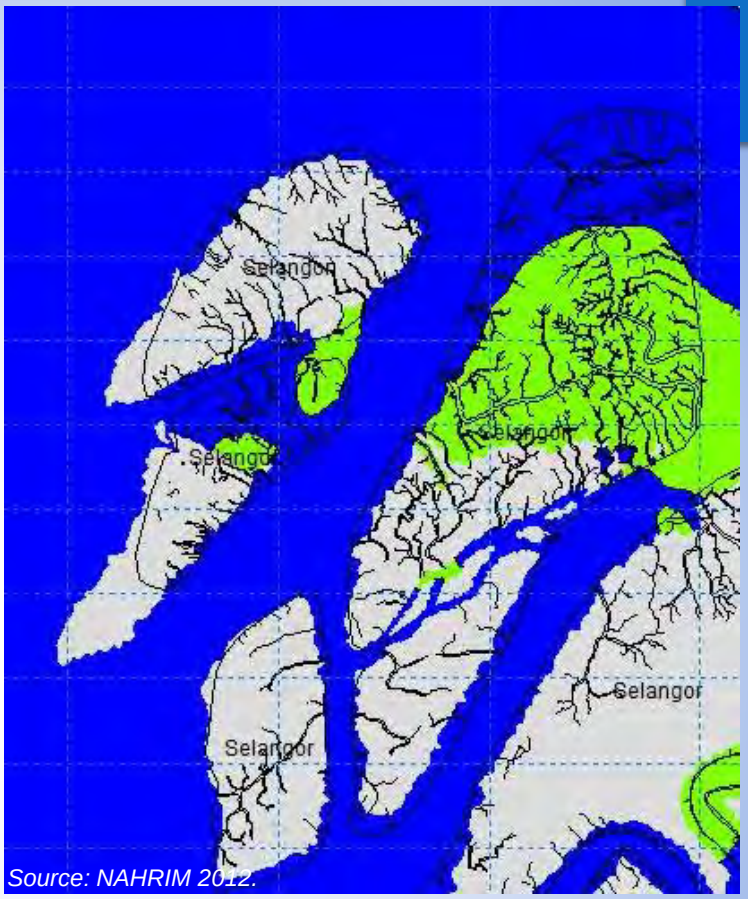
Locals selling local fisheries produce

Existing Land Use Year 2012



1. Main land use is forest (mangrove) and wetlands
2. Settlement concentrated at Bagan Teochew and Bagan Sungai Lima and small settlement of Orang Asli at Pulau Ketam
3. Main economic activity is fisheries

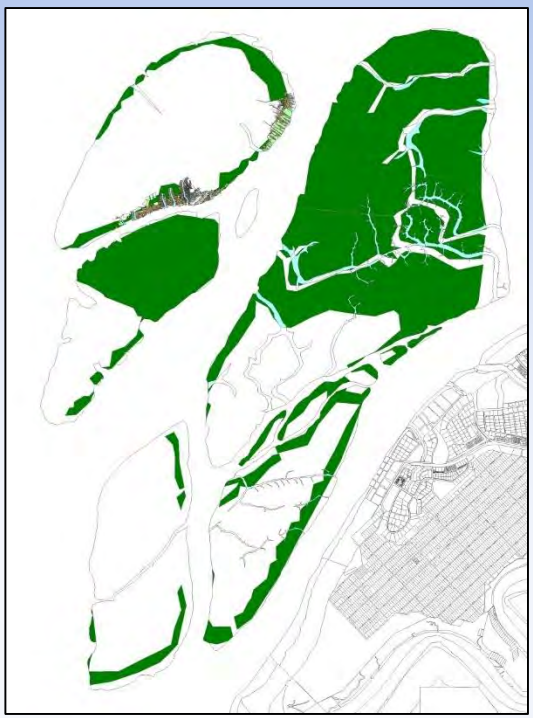
Maximum Water Level Year 2012

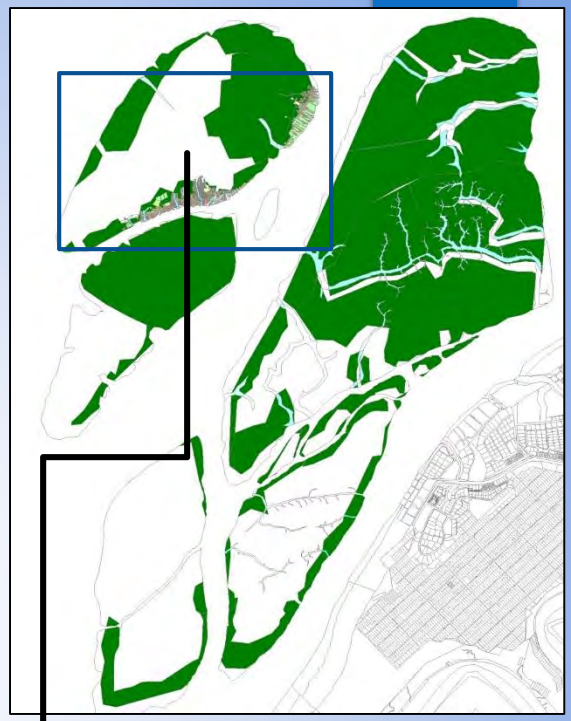


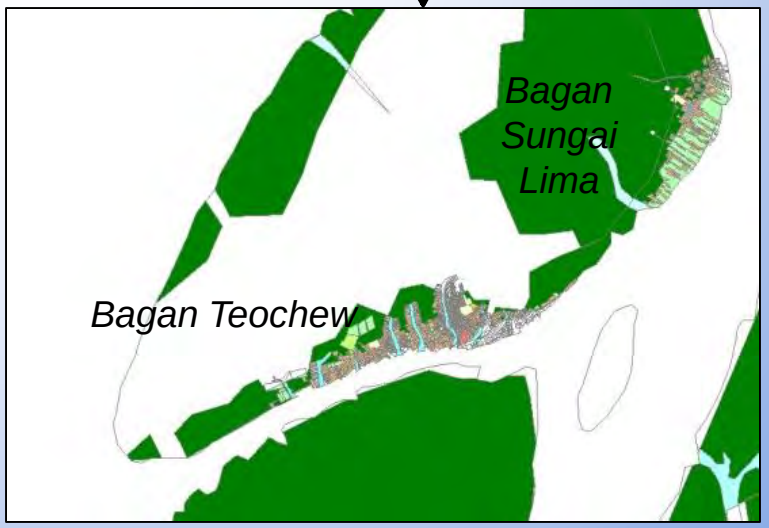
1. Maximum water level of the islands are in between 1.80 meter to 2.00 meter (surface elevation)
2. Highest water level is near north east of Pulau Klang.

Future Land Use (2020)

Areas Will Be Inundated 2020



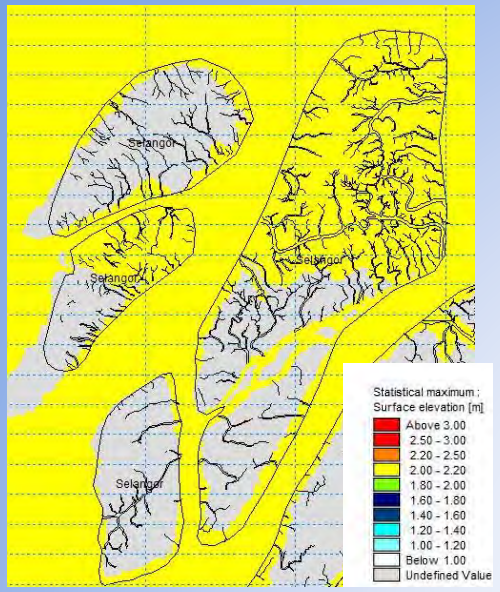




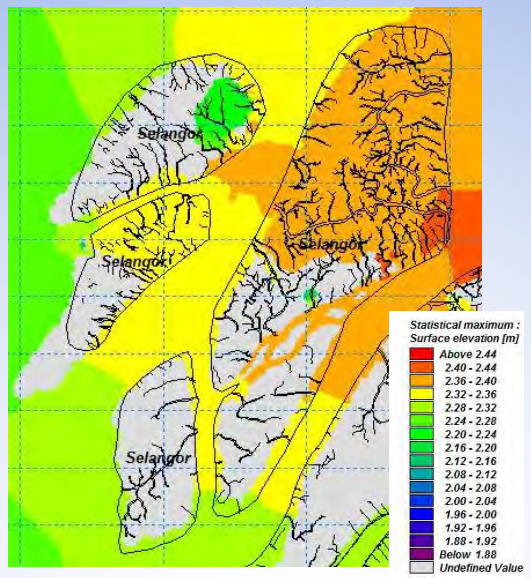
Findings :

1. 94.42% of affected areas are forested areas (mangroves).
2. An approximately 62.23 ha (1.10% of total) of urban settlement will be affected by the SLR, accounted to almost 100% of the populated areas (Bagan Teochew and Bagan Sungai Lima).

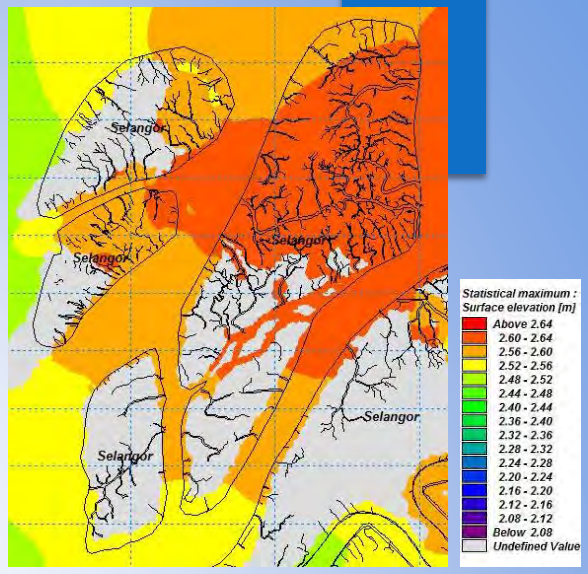
Maximum Water Level SLR 2040



Maximum Water Level SLR 2060

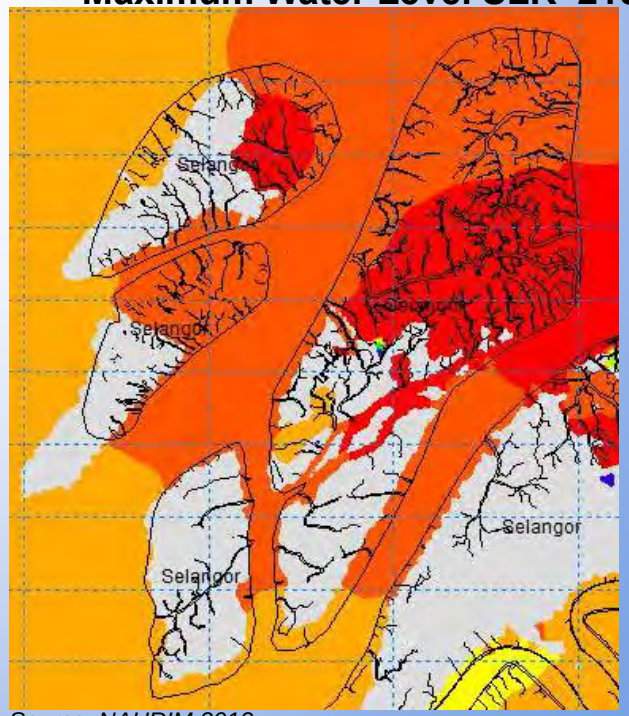


Maximum Water Level SLR 2080



1. Existing maximum water level of the islands are in between 2.25 meter to 2.65 meter (surface elevation), projected to increase to 2.70-2.75 in year 2040.
2. The water level will increases further to 2.75 – 2.80 for Klang Island in 2060. Bagan Teochew of Pulau Ketam will experience increases to 2.8 – 2.85 m.
3. The surface elevation will finally increases to 2.80 – 2.85 and above 2.85 for northeast of Pulau Ketam.
4. Highest water level is near north east of Pulau Klang i.e above 2.85 meter.
5. Almost all existing settlement of Pulau Ketam will be affected.

Maximum Water Level SLR 2100



Source: NAHRIM 2012.

SUMMARY OF IMPACTED ZONE DUE TO COASTAL FLOODING, DAMAGE AND LOSS

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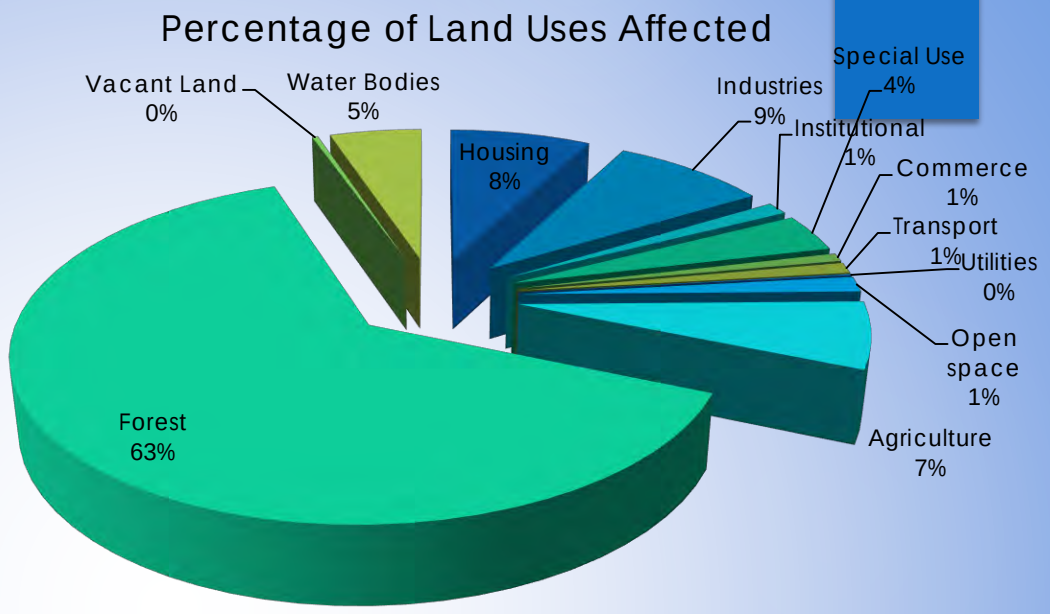
SUMMARY OF IMPACTED LAND USES BY COASTAL FLOODING DUE TO SLR

BLOCK		TOTAL
ZONING	HECTARE	%
Housing	781.98	7.80
Industries	857.19	8.55
Institutional	122.19	1.22
Special Use	374.37	3.74
Commerce	79.46	0.79
Transport	104.75	1.05
Utilities	9.64	0.10
Open space	149.00	1.49
Agriculture	650.79	6.49
Forest	6,349.40	63.36
Vacant Land	32.99	0.33
Water Bodies	510.08	5.09
Total	**10,021.84**	**100.00**



Impacted Land Uses By Coastal Flooding Due To SLR By Territorial Block

BLOCK	KLANG ISLANDS		PORT KLANG		PULAU INDAH		TELOK GONG		PULAU CAREY		TOTAL	
ZONING	HECTARE	%	HECTARE	%	HECTARE	%	HECTARE	%	HECTARE	%	HECTARE	%
Housing	45.91	0.81	430.16	23.77	142.13	14.11	163.78	19.74	-	-	736.07	7.80
Industries	1.86	0.03	533.02	29.45	301.25	29.91	21.06	2.54	-	-	855.33	8.55
Institutional	3.18	0.06	29.91	1.65	68.33	6.78	20.77	2.50	-	-	119.01	1.22
Special Use	-	-	54.41	3.01	280.10	27.81	39.86	4.80	-	-	374.37	3.74
Commerce	1.74	0.03	5.40	0.30	66.67	6.62	5.65	0.68	-	-	77.72	0.79
Transport	9.34	0.17	91.32	5.05	-	-	4.09	0.49	-	-	95.41	1.05
Utilities	0.2	0.00	8.88	0.49	-	-	0.56	0.07	-	-	9.44	0.10
Open space	-	-	124.87	6.90	23.30	2.31	0.83	0.10	-	-	149.00	1.49
Agriculture	-	-	-	-	-	-	269.08	32.43	381.71	51.98	650.79	6.49
Forest	5,325.88	94.42	289.14	15.98	89.58	8.89	292.12	35.20	352.68	48.02	1,023.52	63.36
Vacant Land	31.79	0.56	0.55	0.03	-	-	0.65	0.08	-	-	1.20	0.33
Water Bodies	220.78	3.91	241.97	13.37	35.96	3.57	11.37	1.37	-	-	289.30	5.09
Total	**5,640.68**	**100.00**	**1,809.62**	**100.00**	**1,007.32**	**100.00**	**829.81**	**100.00**	734.39	**100.00**	**4,381.16**	**100.00**

1. The biggest impacted land use is mangrove forest accounts to 6,349.40 ha (63.36%), mainly at Klang Islands.
2. The second biggest is industries accounts to 857.19 ha, mainly at Port Klang and Pulau Indah.

EXAMPLES OF LAND USES FLOOD LOSSES BY TRANSECT (INDUSTRIAL AND RESIDENTIAL /HOUSING LAND & PROPERTY)

REF	Details	Maximum Surface Elevation (Mx)(M)	Estimated Area (Ac.) Inundated	Estimated Industrial Inundated
A	North Port			
T1	Lingkaran Sultan Muhamad 2 industrial area	1.438 m	157.25786 Acres	51.65 Acres
T2	Leboh Sultan Mohammad 1 industrial area	1.947 m		
T3	Taman IKS industrial area	2.599 m		

REF	Details	Maximum Surface Elevation (Mxe)(M)	ESTIMATED AREA (Ac.)/Lot To Be Inundated	Estimated Industrial Inundated	Estimated Commercial Inundated
B	Bandar Sulaiman				
T1	Bandar Sulaiman Industrial Park	3.79 m	81.5448 Acres	18.04 Acres	0.82 Acres
T2	Port Klang Golf Resort	3.83 m			

Ref	Details Teluk Gong	Maximum Surface Elevation (Mxe)(M)	Estimated Area (Ac) Zone Be Inundated	Estimated Residential Property/Land Inundated
C				
T1	Kampung Teluk Gong	1.64 m	459.24 Acres	1.80 Acres
T2	Kampung Teluk Gong	2.10 m		
T3	Kampung Nelayan	2.04 m		
T4	Kampung Nelayan	2.56 m		

Among negative impacts of sea level rise anticipated to the study area are:

1. Increases in size of inundation compound;
2. Increase in depth of water level
3. Increase of inundation areas/flooding areas; and
4. Inflow from opening channel might cause the excess water to flow towards higher ground level in the catchment

CATEGORIES OF FLOOD LOSSES

	Direct losses	Indirect losses
Tangible losses	e.g. building and contents, infrastructures, vehicles, crops, livestock, personal belongings and assets etc.	e.g. costs of rescue operation, aid, medical and lawsuit expenses, disruption to transport, business, commerce, employment etc.
Intangible losses	e.g. lives, injuries, damages to historical and ecological heritage etc	. e.g. stress, anxiety, trauma disruption to lives, loss of community, loss of societal resources etc.

COST FACTOR USED IN QUANTIFICATION OF LOOD LOSS

	Land Uses /Property Loss and Damage	RM/unit	Adjustment to Current Year and Local Context	Proposed Cost Factor (Port Klang 2015)
1	Mangrove Resources	RM 2,157.71 per ha	2,589.25	260,000/km2
2	Commercial	RM 800/m2	1,200.00	1,200,000,000 /km2
3	Industrial	RM 30/m2	69.00	70,000,000/km2
4	Urban house	RM22,000/household	44,000.00	44,000/household
5	Plantation (Oil palm)	RM3500/ha	5,250.00	530,000/km2

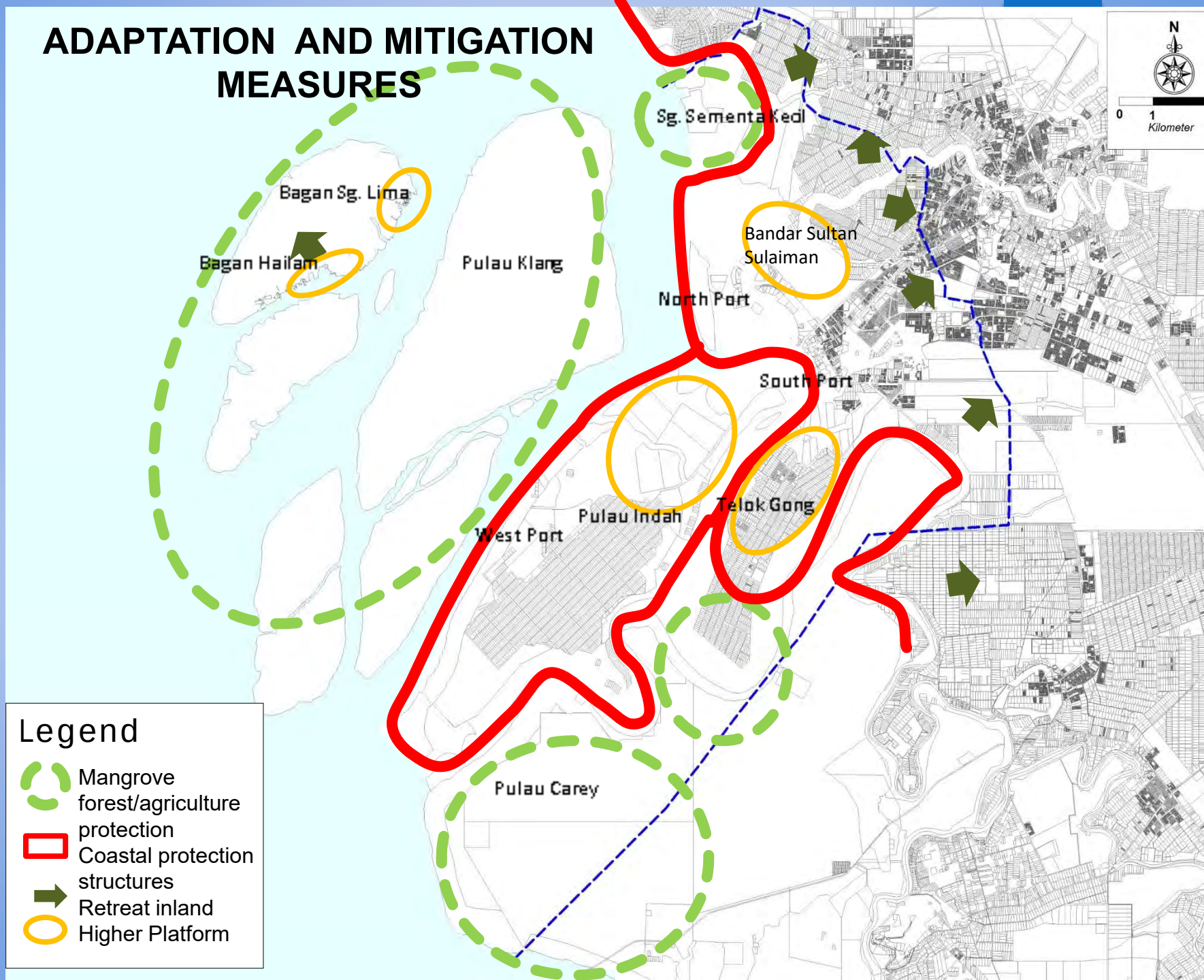
Source :

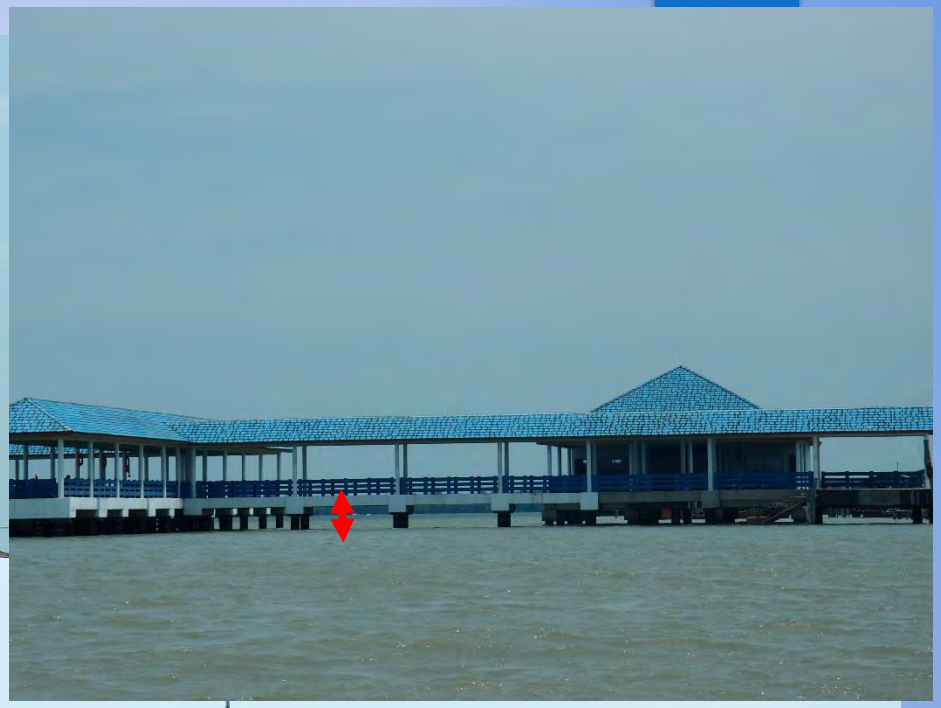
(1) Valuing The Potential Economic Value of Mangroves Resources in Setiu Wetlands, Terengganu, Malaysia: A Preliminary Findings

(2) (3) Flood Loss Assessment in Kota Tinggi, UTM 2014

(4) (5) Flood Loss Assessment of the 2003 Muda River Food, JPS

ADAPTATION AND MITIGATION MEASURES





Pulau Ketam, Klang
15 April 2015

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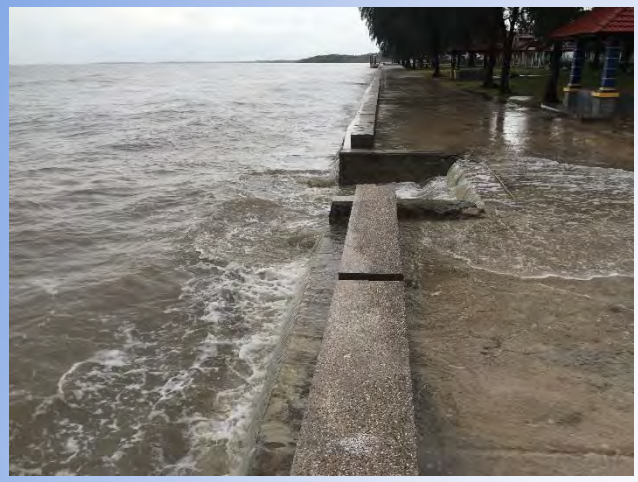
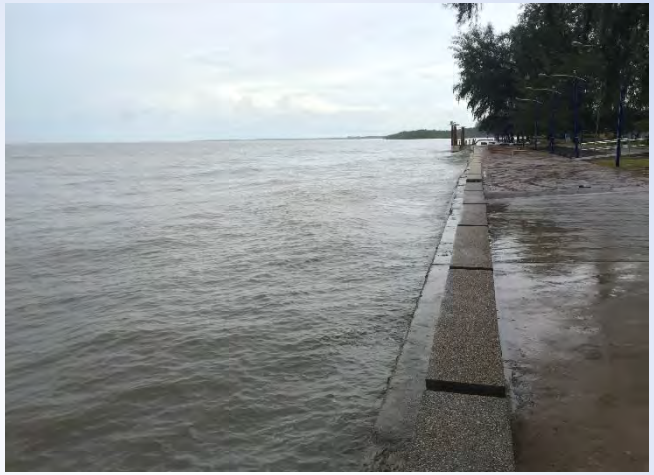
Kelanang Beach (20/09/16 - 7.15am)

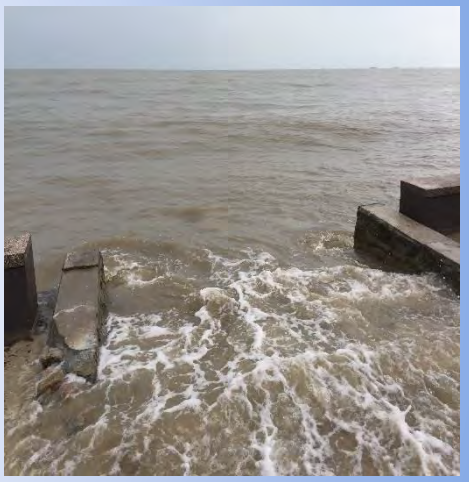


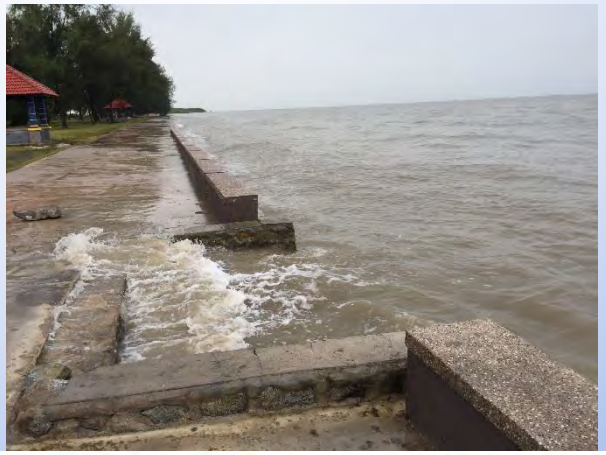


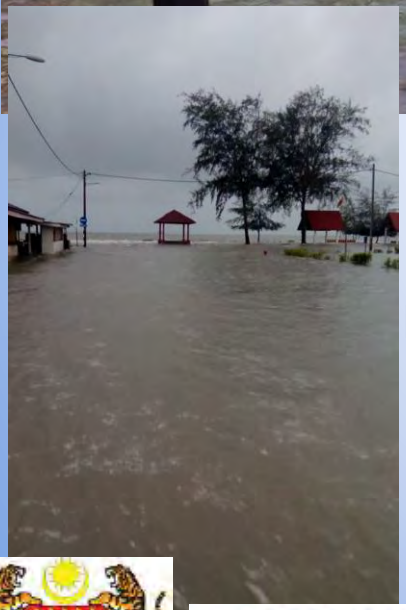

Morib Beach (20/09/16 - 10.15am)

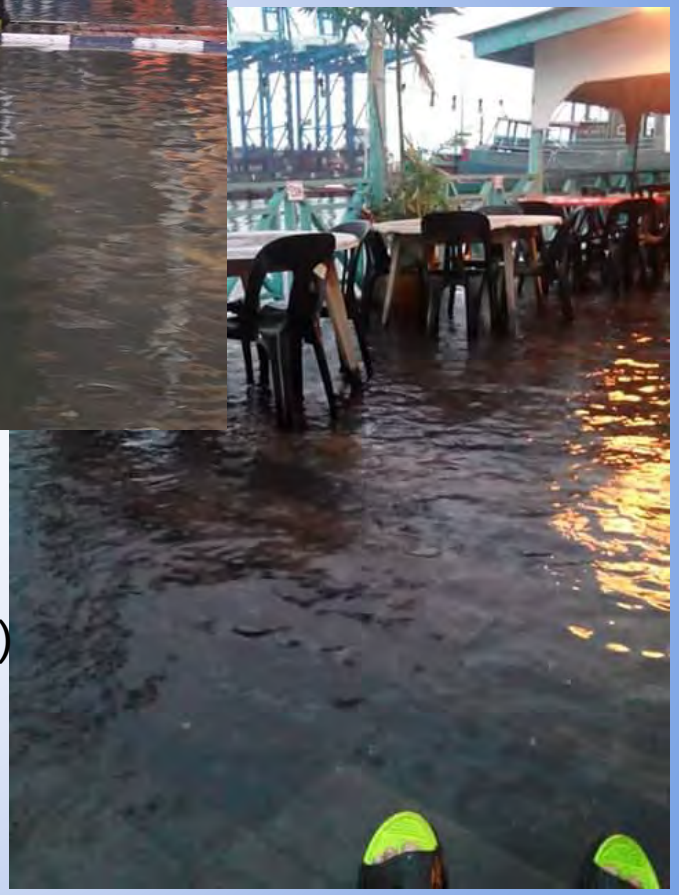












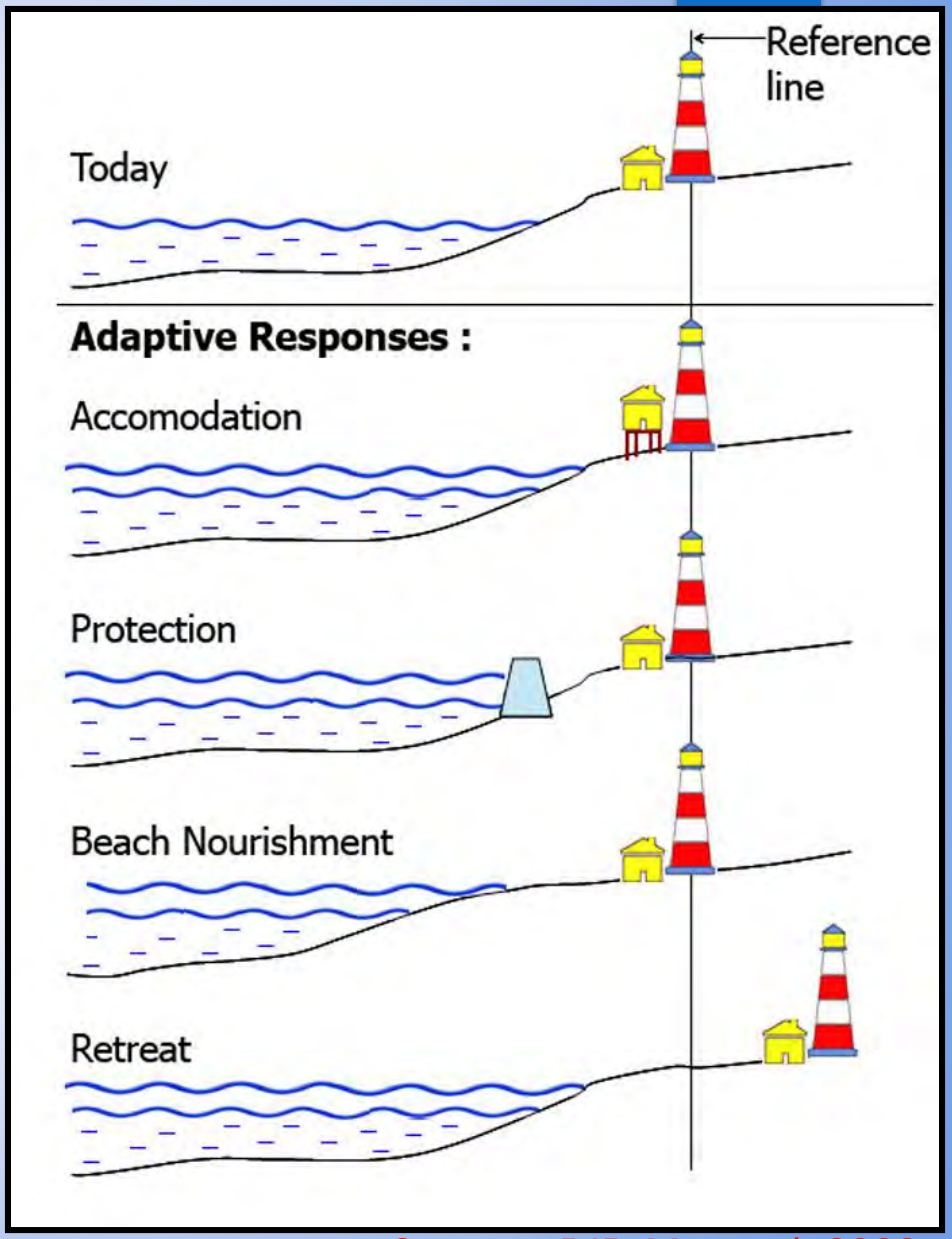
Klang City (20/09/16 - 10.15am)

Klang (20/09/16 - 10.15am)

Adaptation Approaches To SLR

Alternative methods to mitigate the damage of coastal storms and forces are:

i. **Accommodation;**
ii. **Protection;**
iii. **Beach nourishment;**
iv. **Retreat ;**
v. **Do-nothing;**
vi. **Integrated Shoreline Management Plan;**
vii. **Refurbishment on coastal bund;**
viii. **others**

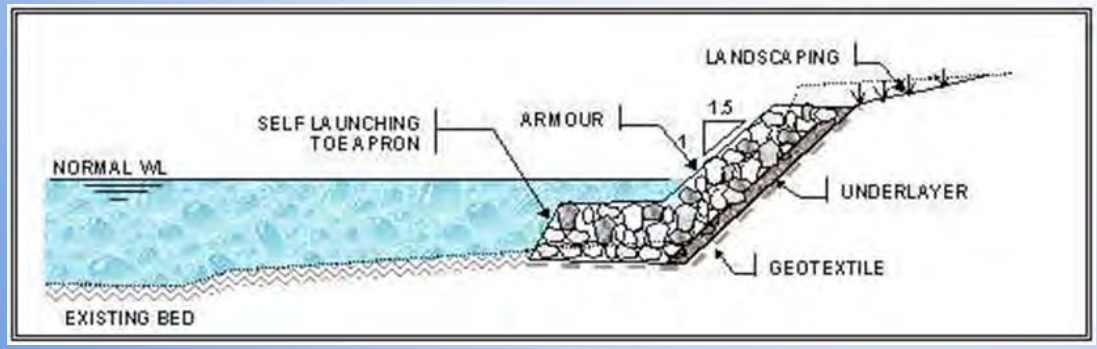


Source: DID Manual, 2009

Adaptation Measures

- **Construction of rock bund / rock revetment**

- **Raising of existing rock revetment / rock bund**



Adaptation Measures

- Raising of jetty / walkway platform levels

- Wave buffer – offshore breakwater / geotube

Adaptation Measures

- Maintenance dredging of river channel / river mouth

- Tidal gate to Prevent salt water intrusion in river system

Adaptation Measures

- **Construction of sand bag along shoreline during Highest tide event**

CONCLUSION

- Natural and anthropogenic climate change will add greater pressure on the resource, jeopardize sustainability, and intensify inter-sectoral and conflicts over water. Therefore, appropriate adaptation strategies on water sector are needed.

- The focus of climate change & sea level rise studies must begin to shift from generic impacts assessment to more focused and specified assessment, adaptation and response mechanisms based on typical planning horizon (i.e. from 2020, 2050, 2100)

WAY FORWARD

- SLR have potentials to change:-
  - coastal natural processes,
  - marine habitats and ecosystems,
  - effecting infrastructure
  - socio-economy
- Disaster can be minimized /avoided with KNOWLEDGE and PREPAREDNESS
- Further Research on Impact of Sea Level Rise
  - ✓ Salt Intrusion Impact due to SLR
  - ✓ Impact of climate change & storm surges to SLR in Malaysia based on AR5 latest finding.

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Thank You