PROJECTION OF SEA LEVEL CHANGE AND POTENTIAL INUNDATION COVERAGE ALONG THE COAST OF SANDAKAN TOWN, SABAH

DUNSTAN ANTHONY

THESIS SUBMITTED IN FULLFILLMENT FOR THE DEGREE OF MASTER OF SCIENCE (MARINE SCIENCE)

BORNEO MARINE RESEARCH INSTITUTE
UNIVERSITY MALAYSIA SABAH
KOTA KINABALU
2017

UNIVERSITI MALAYSIA SABAH

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DEGREE	:	**MASTER OF SCIENCE (MARINE SCIENCE)**
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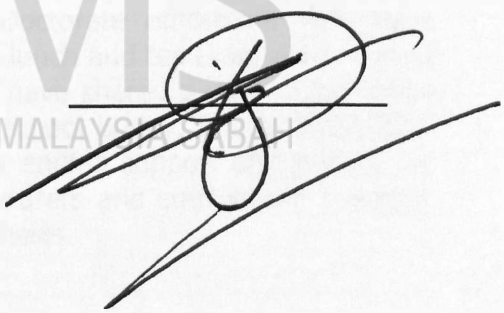

ACKNOWLEDGEMENT

'Where there is a will, there will be a solution', famous olden folk's maxim to motivate someone whose currently working on something good for their future. This maxim really suits my motivation to face the journey of two years striving to finish this study successfully. I would like to take this opportunity to express my deepest gratitude and appreciation to my beloved wife, Rothsctah Jukin for giving me undisputed support for the period of two years in whatever circumstances we face in life. Undisclosed feeling of indebted to my supervisor, Assoc. Prof. Dr. Than H. Aung whom have groom my disciplinary and knowledge in Marine Science field with the numerous notes, tips and valuables information which certainly hard to obtain from lectures attendees. To my co-supervisor, Dr. Ejria Saleh, it wouldn't be possible for me to complete this journey without your assistance in scientific writing skills, managerial ability and understanding that lead to the completion of this thesis. Furthermore, I would like to extend my gratitude and feeling blessed to have such an understanding bosses, Ir. Hj. Mohd Radzi Abd Hamid and not to forget Dr. Justin Sentian for the trustworthy and kindness of allowing me to get some funding for my study and also for the motivation and guidance to improved my result presentation. Last but not least, there are so many people that have persuaded and support me directly or indirectly especially to Abdul Munir Ladoni @ Danny whom kindly allowing me to use his desktop PC for my numerical model simulation, Russel Felix Koting, a good colleagues whom have help me a lot in information sharing throughout the study, Mr. Roland, Miss Joan, Mr. Faizan Hassan, Dr. German Bueno, a PhD and Post Doctorate officemate who have become social buddy and fruitful discussion during lunch and tea time, not to forget to Miss Archier Chung, long lost dive mate whom have shared a lot of information on biological aspect of the marine, my best high school buddy, Bobby Christ Ngui and Reno Peter for their understanding and never ending support and prayers for my success and last but not least to all BMRI lecturers and staff whom I believe contributed to the quality accomplishment of this thesis.

Dunstan Bin Anthony

15 June 2016

ABSTRACT

In recent years, there has been an increase in the frequency and severity of extreme weather condition particularly in coastal areas which are ostensibly linked to changing climate. Recent climate change analyses indicated many uncertainties at global observation scale, thus investigating the need for an intensive examination at local level to understand vulnerability and develop adaptive capabilities. This study focuses on the need to evaluate the projection of future sea level inside Sandakan Bay and its potential impacts in the form of flooding, inundation and beach erosion. The main objectives of this study are to determine the sea level trend based on historical sea level data in Sandakan; to simulate future SLR in the year 2020, 2040 and 2060 and to identify and calculate future inundation area due to SLR for Sandakan Town coast. The 18-year Sandakan tidal data (1994-2011) was used to determine MSL and sea level trends. The assessment of potential flood prone area was done with a numerical model tool, the MIKE 21 Flexible Mesh (FM) and Geographic Information System (GIS). Digital Terrain Model (DTM) with a 5m resolution and 3km width from water edge, integrated with bathymetry produced swift inundation pattern of the water-land boundary. The model calibration used measured water level and current meter data collected from 8th to 22th May 2012. The inundation map was drawn and calculated using Geographic Information System (GIS). Result shows that MSL is 2.706 m while hourly, daily, monthly and yearly sea level trends are 6.13, 5.51, 5.89 and 6.78 mm/yr respectively. The 2020, 2040 and 2060 projected water levels were estimated at 49.04, 171.6 and 294.2mm respectively from the baseline year of 2012. Five potential impacted areas were identified, namely: Bumputera Sim-Sim Village (A), Old Sandakan Town (B), Sandakan Port Authority (C), Industrial Zone of Jalan Bokara to Jalan Sapi (D), and IOI Edibles Oil Sdn Bhd (E). For 2060, the total potentially inundated area for Area A, B, C, and D are 1 km^2 and 0.429 km^2 for Area E. This study highlights the necessity of incorporating other day-to-day influencing factors and extreme events on the identification of inundation areas based on tidal data to obtain more accurate inundation profile due to sea level rise.

ABSTRAK

UNJURAN PERUBAHAN ARAS LAUT DAN POTENSI KAWASAN INUNDASI DI SEPANJANG PANTAI BANDAR SANDAKAN, SABAH

Sejak beberapa tahun kebelakangan, peningkatan kekerapan dan ketidaktentuan keadaan cuaca yang melampau khususnya di pesisir pantai amat dikaitkan dengan perubahan iklim. Analisis perubahan iklim terkini menunjukkan banyak ketidaktentuan pada skala pemerhatian global, dan dengan itu, perlunya kajian intensif pada tahap tempatan untuk menilai impak dan membangunkan langkah adaptasi yang wajar diperingkat lokal. Kajian ini menumpukan keperluan untuk menilai unjuran aras laut masa depan di kawasan perairan Teluk Sandakan dan potensi impaknya dalam bentuk banjir, inundasi dan hakisan pantai. Objektif utama kajian ini adalah untuk menentukan tren aras laut berdasarkan sejarah data pasang surut air laut di Sandakan; untuk mensimulasikan keadaan kenaikan aras laut di masa depan pada tahun 2020, 2040 dan 2060 dan untuk mengenal pasti kawasan inundasi dan mengira keluasan kawasan terjejas akibat fenomena kenaikan aras laut untuk persisiran pantai bandar Sandakan. Data 18 tahun air pasang surut Sandakan (1994-2011) digunakan untuk menentukan nilai aras laut purata (Mean Sea Level) *dan tren aras laut. Penilaian dan penentuan kawasan berpotensi inundasi dilakukan dengan model numerikal,* MIKE 21 Flexible Mesh (FM) dan Geographical Information System (GIS). Digital Terrain Model (DTM) *dengan resolusi 5m dan lebar 3km dari gigi air yang diintegrasikan dengan cerapan kedalaman laut menghasilkan corak inundasi yang terperinci dan lebih tepat untuk sempadan laut-darat. Pengkalibrasian model menggunakan data pasang surut dan cerapan kelajuan arus yang dicerap dari 8 hingga 22 Mei 2012. Hasil analisis data pasang surut menunjukkan MSL ialah 2.706m manakala tren aras laut mengikut jam, hari, bulan dan tahun adalah masing-masing 6.13, 5.51, 5.89 dan 6.78 mm/tahun. Aras air yang diunjurkan untuk 2020, 2040 dan 2060 dianggarkan pada 49.04, 171.6 dan 294.2mm berdasarkan model asas tahun 2012. Lima kawasan terjejas dikenalpasti iaitu: Perkampungan Bumiputera Sim-Sim (A), Bandar Sandakan (B), Lembaga Pelabuhan Sandakan (C), Zon Perindustrian Jalan Bokara ke Jalan Batu Sapi (D) dan IOI Edibles Oil Sdn Bhd (E). Untuk tahun 2060, jumlah kawasan inundasi berpotensi untuk Kawasan A, B, C, dan D adalah 1 km^2 dan 0.429 km^2 untuk Kawasan E. Kajian ini menjelaskan keperluan menggabungkan beberapa faktor hari demi hari yang mempengaruhi dan peristiwa ekstrim untuk pengenalpastian kawasan inundasi berdasarkan data air pasang-surut bagi mendapatkan profil inundasi lebih tepat akibat fenomena peningkatan aras laut.*

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LIST OF ABBREVIATIONS

ASEAN	-	Association of South East Asian Nation
BMRI	-	Borneo Marine Research Institute
DEM	-	Digital Elevation Model
DHI	-	Danish Hydraulic Institute
DID	-	Drainage and Irrigation Department
DSMM	-	Department of Survey and Mapping Malaysia
DTM	-	Digital Terrain Model
ENSO	-	El - Niño and Southern Oscillation
HAT	-	Highest Astronomical Tide
HD	-	Hydrodynamic
ICZM	-	Integrated Coastal Zone Management
IfSAR	-	Interferometric Synthetic Aperture Radar
IOC	-	Intergovernmental Oceanographic Commission
IPCC	-	Intergovernmental Panel on Climate Change
MSL	-	Mean Sea Level
MMD	-	Malaysia Meteorological Department
NAHRIM	-	National Hydraulic Research Institute of Malaysia
NCES	-	National Coastal Erosion Study
NOAA	-	National Ocean and Atmospheric Administration
NOD	-	National Oceanographic Directorate
PWD	-	Public Work Department
SLR	-	Sea Level Rise
SOP	-	Standard Operating Procedure
UMS	-	University Malaysia Sabah
VLM	-	Vertical Land Movement

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CHAPTER 1

INTRODUCTION

1.1 Preface

As a maritime country, Malaysia relies heavily on the rich natural resources from its thick and virgin forest reserved towards its white sandy beaches and crystal clear waters especially, in East Malaysia or North Borneo which is also known as the Land below the Wind, Sabah. However, the demand for development and due to population growth worldwide, it has resulted in the increase of the release of greenhouse gases which is one of the contributors of the globally discussed issue now known as The Climate Change. Presently, Malaysia is not exempted from experiencing the impacts of climate change even though it is located in the equator, where conceivably the incumbent impact is expected to be slower. The Climate Change had brought many occurrences and one of it is the rising of the sea level. Therefore, this study focuses on the impacts of Sea Level Rise (SLR) for Sandakan town coast, one of the largest districts in Sabah.

The impacts of SLR literally focus on the inundation potential due to the rising sea level as a result of climate change. The district of Sandakan is categorized as one of the largest low lying area in the Eastern Coast of Sabah (Sabah Town and Regional Planning, 1999) which makes it crucial for a study being carried out in the district.

Moreover, the coastal areas of Sandakan Bay, where Sandakan town is located, are among the most densely populated Water Village settlement type of houses (Department of Statistics Malaysia, 2010). These are among the primary reasons for the selection of Sandakan as a study area. The coastal zone of Sabah contains various kinds of valuable natural resources such as mangrove mudflats, swamps, sandy beaches and coral reefs. Sabah is blessed to be surrounded by beautiful beaches and islands. In addition, Sabah is part of the Coral Triangle area and classified as among the most diverse marine resources for both biological and chemical resources in the world and is equally distinguished similar to the Caribbean and Amazon. Apparently, the famous saying "beautiful is just temporary" seems to fit the ecosystem landscape in Malaysia due to the incumbent and growing impacts of climate change throughout the world. In recent years, researchers throughout the world had become more concern about the climate change phenomena and its effects to the human population and the entire world as a whole. One of the impacts that gained attention and has become more popular worldwide is SLR. The study of SLR has many different facets (IOC, 2002). However, this study focuses on analyzing the sea level data from historical tidal records and therefore producing inundation potential coverage map based on the trends obtained from the records. This is important as it was reported that the sea level is not only rising, but also accelerating (Douglas, 1997).

Malaysia, Philippines and Indonesia are located in the equatorial region and experiencing two seasonal monsoons known as the Northeast Monsoon and the Southwest Monsoon. The Philippines is also impacted by tropical cyclones and typhoons from July to November whereby the extent of low-lying coastal areas, monsoonal rains, and numerous islands, mark this region as highly vulnerable to coastal flooding and erosion (Mcleod *et al.,* 2010). In recent years, the growing consensus among sea-level researchers that the global SLR in the past 100 years has been considerably faster than in the previous two millennia (Douglas, 2000). In this sense, global SLR mean does not translate into a uniform rise in local sea level in coasts and estuaries around the World (Yan Ding *et al.,* 2013). The impacts of SLR differ regionally in terms of annual people growth, coastal wetland changes and loss, damage and adaptation costs (NCES, 1985). Typically, coastal erosion and

flooding were based on observed physical parameters, such as water depth, salinity and inundation profile and duration in which such approach is often limited by availability of observed data and may not have temporal and spatial resolution to forecast changes (Yan Ding *et al.,* 2013). It is undoubtedly that, SLR predominant impacts are coastal erosion, inundation or flooding and salt water intrusion. Research focuses are currently concentrated on the implication of SLR events towards the ecological, biological and physical and socio-economic up to development and adaptation planning of the coastal zone (James *et al.,* 1991). Various methods have been applied to foresee the impacts of SLR especially on the coastal features. The latest records for overview of SLR condition in Malaysia was done by the National Hydraulic Research Institute of Malaysia (NAHRIM) in 2010 in which comparison of the acceleration rate from historical tidal records, satellite altimetry and further integrated with the Global climate model from AR4 (IPCC, 2007) projection. Thus, this study will be the primary source of reference for SLR studies in Malaysia.

1.2 The Importance of Local Sea Level Rise Assessment

It is certain that the world acknowledges the fact that climate change is really happening and impacting the livelihood and ecosystem balance of the earth. The Inter-Governmental Panel for Climate Change (IPCC) is the responsible perhaps trustworthy and most referred source for climate change related information throughout the world. This particular study is trying to look into localized impacts of SLR at the coastal region. Nevertheless, SLR impact is inevitable regardless of geographical advantages since the effect is noticeably slow and consistence in progress. By definition, local SLR is interpreted as relative or absolute due to the rising and falling of earth surface over time where relative changes may be observed even though the absolute height of the ocean remains the same (Church *et al.,* 2006). Hence, it is crucial to undergo localized sea level rise impact assessment for the coastal stretches of Sandakan town as a reference to the local municipal council development prospectus and risk assessment guideline.

1.3 Sea Level Rise in Sabah

The undulating shoreline of Sabah certainly creates a challenging research prospectus for inundation coverage due to SLR. The recent finding for SLR research for each state in Malaysia reported in The Sea Level Rise Study in Malaysia in 2010 executed by National Hydraulic Research Institute of Malaysia (NAHRIM). This study integrates numerical modelling simulation, Digital Elevation Model (DEM) and SLR rate within the coastal area across Malaysia into the hydrodynamic model to produce inundation potential. Hence, this study has depicted a different assessment point of view for the SLR scenario at the particular coastal stretches. It is also acknowledged from literature review about the importance to undergo local sea level studies since local (or relative) sea-level change is spatially non-uniform due to regional or local factors that affect Vertical Land Movement (VLM) by tectonic movements, subsidence and sedimentation (Mcleod *et al.,* 2010). Historical records of sea-level changes confirmed that localized land or sea movements affect current sea level at different rates and over different time and spatial scales (Harvey and Mimura, 2006). Hence, taking into consideration the importance of VLM station that has been established, this study will become the primary source for future reference in Sandakan. Presently, it is obvious that Sabah is undergoing rapid coastal development due to the increase of population demand as well as the improved economic stability of the State. In conjunction with that, a major consideration that has to be done for Sabah coast with respect to SLR issue currently is the assessment of Coastal Vulnerability Index and Inundation Map due to flooding events (Sabah Town and Regional Planning Department, 1999). Furthermore, the compounding impacts of SLR can also be seen on salinity changes on agricultural landfill where salt water intrusion research and assessment become necessary. Presently, there is still no in-depth study on localized scale for SLR on any of the Sabah coastlines. Integrated Coastal Zone Management (ICZM) of Sabah which has been initiated and carried out by the state government in collaboration with Danish Cooperation for Environment and Development (DANCED) in the late 1998 to 1999 is one of the primary references and guidelines on coastal zone and description of Sabah coastal characteristics in general. There are increasing numbers of study related to the coastal ecosystem in Sabah but mostly

concentrated on socio-economic interaction, coastal protection agendas and water quality interaction which are not related to SLR. Additionally, Universiti Malaysia Sabah (UMS) had been analyzing tidal records for SLR assessment in Kudat, Tawau, Kota Kinabalu and Sandakan (De Souza, 2012).

1.4 Significance of Study

The selection of Sandakan district for this study is based on a few fundamental reasons. The State of Sabah consists of 23 districts and the Sandakan land area is around 190,151 hectares. The Sandakan coast is occupied by mangroves which are among the largest mangroves forest reserves in Malaysia with a total length of 282.7 km (Sabah Forestry Department, 2012). On the other hand, two (2) of Sabah districts fall entirely within the Coastal Zone where Sandakan being the largest delineated low lying area, and the other one is Kuala Penyu, located on the west coast of Sabah (Sabah Town and Regional Planning Department, 1999). In addition, the low elevation areas and high number of river mouths are located in the districts of Tawau, Semporna, Lahad Datu, Sandakan and Kudat which are identified as vulnerable to SLR (NAHRIM, 2010). It is also reported that the highest SLR inundation projection occurs in the northern and eastern sectors of Sabah coast where Sandakan district is located. Moreover, Sandakan district has the highest population at the inter-tidal area (Pedersen *et al.,* 2010). Last but not least, low lying areas and coastal zones are the most vulnerable land portion that potentially affected by SLR event. Figure 1.1 indicates the land part of Sabah coastal zone where Sandakan district is gazette as the largest area being categorized as coastal zone.

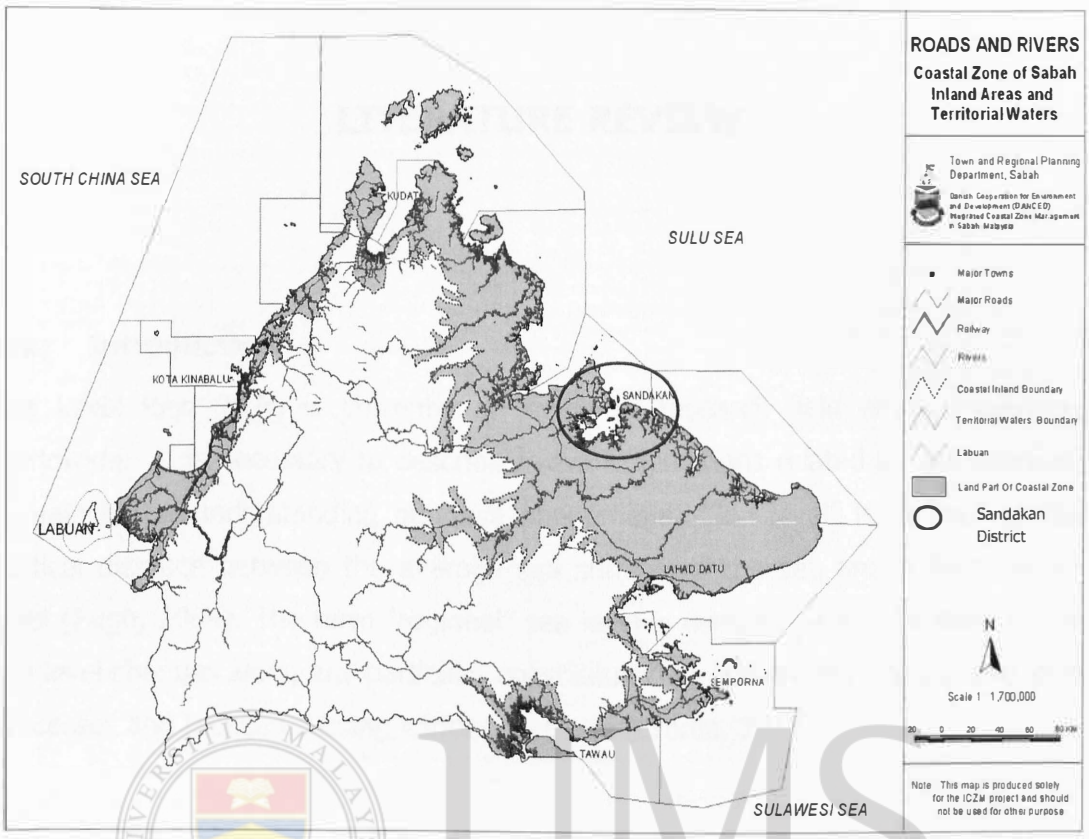

Figure 1.1 : Land part of Sabah Coastal Zone
Source : Sabah Town and Regional Planning Department (1999)

1.5 Objectives

The primary objectives of this study are as follows:

i.) To determine the sea level trend based on historical sea level data in Sandakan;

ii.) To simulate future SLR in the year 2020, 2040 and 2060; and

ii.) To identify and calculate potential inundation area due to SLR for Sandakan Town coast.