

**THE REPUBLIC OF MAURITIUS  
MINISTRY OF ENVIRONMENT, SUSTAINABLE DEVELOPMENT, AND DISASTER AND  
BEACH MANAGEMENT**

**GUIDELINE FOR  
CLIMATE CHANGE ADAPTATION STRATEGY  
(COASTAL SETBACK)**

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**JAPAN INTERNATIONAL COOPERATION AGENCY  
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## Abbreviation

Abbreviations	Proper Name
AAP	African Adaptation Programme
AR5	Fifth Assessment Report of IPCC
BLP	Building and Land Use Permit
BoM	Bank of Mauritius
CCD	Climate Change Division
DEM	Digital Elevation Model
DRR	Disaster Risk Reduction Strategic Framework and Action Plan
EIA	Environment Impact Assessment
FAO	Food and Agriculture Organization
GIS	Geographic Information System
GMSLR	Global Mean Sea Level Rise
GPS	Global Positioning System
HWM	High Water Mark
ICZM	Integrated Coastal Zone Management
IOC	Indian Ocean Commission
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
LECZ	Low Elevation Coastal Zone
MEA	Mid and East Antrim
MHL	Ministry of Housing and Lands
MMS	Mauritius Meteorological Services
MOESDDBM	Ministry of Environment, Sustainable Development, and Disaster and Beach Management
MUR	Mauritian Rupee
NDRRMC	National Disaster Risk Reduction and Management Centre
PPG	Policy Planning Guideline
SIDS	Small Island Developing States
SLR	Sea Level Rise
UNEP	United Nations Environment Programme
VCA	Village Council Area
WGII	Working Group II of IPCC
WMO	World Meteorological Organization

## Introduction

### 1.1 Global Context of Climate Change

According to latest available scientific reports<sup>1</sup> and observations<sup>2</sup>, Small Island Developing States (SIDS) are already experiencing the accentuated, worsening and damaging adverse impacts of climate change. The Fifth Assessment Report<sup>3</sup> (AR5) indicates the following four main challenges to SIDS pertaining to climate change, these are:

- I. Risk of death, injury, ill-health or disrupted livelihoods in low-lying coastal zones and small island developing states and other small islands, due to storm surges, coastal flooding and sea-level rise;
- II. Systematic risks due to extreme weather events leading to breakdown infrastructure networks and critical services such as electricity, water supply and health and emergency services;
- III. Risk of loss of marine and coastal ecosystems, biodiversity and the ecosystem goods, functions and services they provide for coastal livelihoods, especially for fishing communities in the tropics and the Arctic; and
- IV. Risk of food insecurity and the breakdown food systems linked to warming, drought, flooding and precipitation variability and extremes, particularly for poorer populations in urban and rural settings.

The climate change risks for SIDS in the AR5 are summarized in Figure 0.1 below:

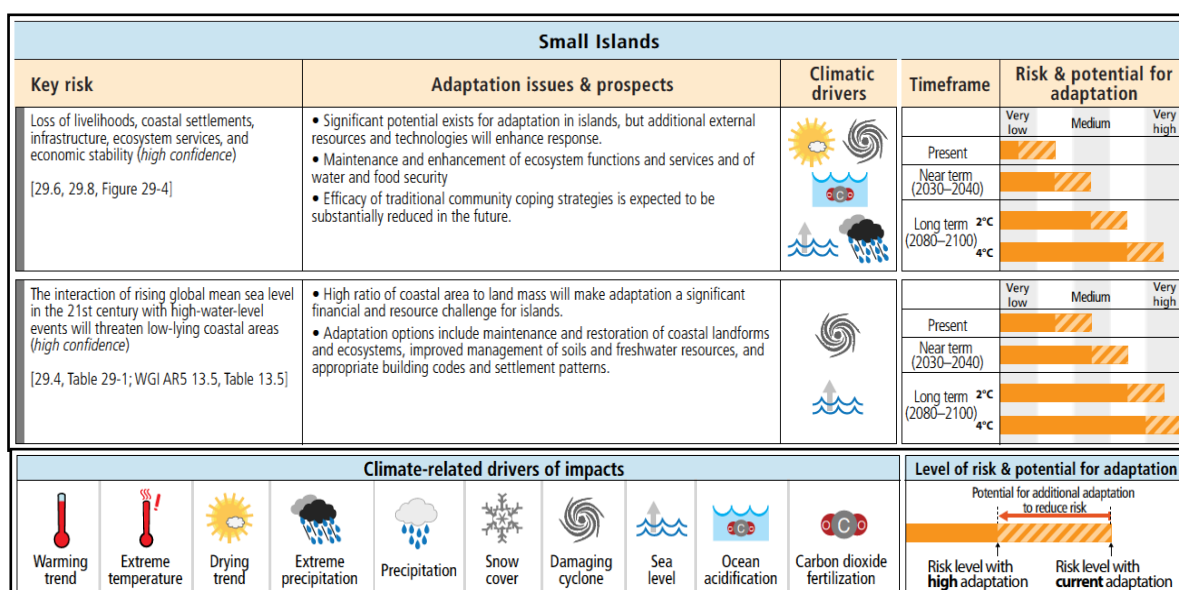


Figure 0.1: Climate-related Drivers of Impact in SIDS

### 1.2 Climate Change and its adverse impacts on Mauritius

Mauritius as a SIDS is highly vulnerable to adverse impacts of climate change. According to the latest World Risk Report 2014, Mauritius is ranked as the 14th country with the highest disaster

<sup>1</sup> Emerging Issues for Small Islands Developing States (UNEP Foresight Report), 2014.

<sup>2</sup> Structured Expert Dialogue Report, 2015.

<sup>3</sup> Fifth Assessment Report (Synthesis Report) by IPCC (Intergovernmental Panel on Climate Change), 2014.

risk and ranked 7<sup>th</sup> on the list of countries most exposed to natural hazards. The threatening impacts of climate change are already being felt through an accelerated sea level rise, accentuated beach erosion, increase in frequency and intensity of extreme weather events such as flash floods as well as decreasing rainfall patterns.

**Some of the key observed impacts and projections for Mauritius are:**

- Compared to 1961-90, the average temperature in Mauritius increased by 0.74 – 1.1°C. The average temperature is expected to further increase up to 2°C by 2070<sup>4</sup>;
- A decreasing trend in annual rainfall of around 8% over Mauritius since the 1950s, along with more frequent and severe droughts. Projection indicates that the utilizable water resources will decrease further by up to 13% by 2050<sup>4</sup>;
- Warmer temperatures and milder winters favour higher incidence of pests and diseases. Overall, agricultural production may be expected to decline by as much as 30% leading to concerns over food security by 2050;
- Analysis of Port Louis data for the period 1987-2007 gives a mean sea level rise of 2.1 mm/year for the 10 years in question (source: Mauritius Meteorological Services). However, figures of sea level rise from the University of Hawaii indicate a mean sea level rise of 5.6 mm/year for the period 2003-2012 (source: Sea Level Rise Centre of University of Hawaii). It is projected that beaches, which are the pillars of the tourism industry will slowly disappear carrying away with them possibly over USD 50 million in value added in the sector by 2050;
- Corals which are food and refuge for fish and other marine organisms are being bleached. In 2003, the percentage of completely bleached corals at Ile aux Benitiers, Belle Mare, Poudre d'Or and Albion were 56, 11, 22, and 2% respectively. Coral bleaching also occurred in 1998, 2004 and 2009. With predicted reduction in live corals by 80-100% by the year 2100, the coastal zones will without doubt deteriorate and coral reef fish population will decrease, highly impacting coastal communities and putting the livelihood of fishers at stake;
- Climate change is also impacting on the fisheries sector with frequent fish mortality in shallow water as well as lowered and erratic fisheries productivity and availability. With increase in sea temperature, the size and location of fish stocks and fish migration pattern are affected. Migratory shifts in tuna aggregations may disrupt the local seafood hub activities and other fish based industries;
- Based on the coastal erosion study<sup>5</sup> carried out by the JICA in collaboration with the Government of Mauritius, it has been found that 17% of the beaches are suffering from long term erosion (representing about 13km of beaches); and
- According to the DRR Report<sup>4</sup> the following point elements are at risk of coastal inundation (due to surges and SLR),
  - Flood Hazard: 19-30 km<sup>2</sup> of agricultural land, 5-70 km<sup>2</sup> of built up land, 2.4-3 Km of motorway; 18-29 Km of main roads, 68-109 Km of secondary roads
  - Coastal Inundation: 12.2 km<sup>2</sup> of built-up land, 11.8 km<sup>2</sup> of expansion areas, 60 km of primary and 80 secondary roads.

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4 DRR Strategic Framework and Action Plan, MOESDDBM, 2013

5 The Project for Capacity Development on Coastal Protection and Rehabilitation in the Republic of Mauritius by JICA (Japan International Cooperation Agency), 2015

### 1.3 Purpose of Guideline

In the approved National Climate Change Adaptation Policy Framework for the Republic of Mauritius (Ministry of Environment and Sustainable Development, 2012), the Government of Mauritius identified coastal zone management as one of the priority sectors for adaptation. Following consultation with stakeholders on the project<sup>6</sup> formulation of the coastal setback guideline was agreed. The implementation of appropriate coastal setback can have multiple benefits such as enhancement of conservation ecosystems, adaptation for sea-level rise, sustainable land use, sustainable coastal development, future investment, engagement of the tourism sector in adaptation and sustainable development, disaster risk reduction and others.

The setback is a solution which can contribute to the above issues. There are various approaches to formulate and promote setback. One of the most common approaches which is integrated with the PDCA<sup>7</sup> cycle is introduced in this guideline as a model example. This guideline attempts to propose indicative setbacks for coastal areas identified with erosional characteristics, and which are vulnerable to adverse impacts of climate change. It also provides a mid-long term approach for the refinement and formulation of site specific setbacks based on refined data.

This guideline, which is also the first of a series of guidelines will address setback as one of the proactive measures, taking on board core parameters such as: long term erosion, sea level rise, wave surges during extreme events, environmental sensitive areas and historical features among others. Its main objectives are to:

- i. Guide planners, resource managers, developers and policymakers in selecting most appropriate setback, based on the site specificities and potential risks and vulnerabilities; and
- ii. Serve the basis for the formulation of the customized tool on coastal setbacks as well as for awareness raising.

### 1.4 Desk Study - Gaps & Needs Analysis

During the preliminary phase of the project<sup>8</sup> a Gaps and Needs Analysis was carried out through online survey and a desk study exercise. As a first step, a detailed mapping exercise was conducted to take stock of the current situation climate change activities/projects/ programmes in Mauritius. Organizations from line ministries, parastatal bodies, municipal/district councils, international development partners, local associations, private sector, academia and NGOs were targeted. Some 80 organizations from various sectors were surveyed between 25<sup>th</sup> September 2014 and 13<sup>th</sup> December 2014, using a detailed questionnaire. The response rate for the survey was about 90%. In addition, close to a dozen in-person interviews were conducted to gain further insight into organizations initiatives/projects/programmes related to climate change.

The figure below illustrates the activities in which organizations consulted are involved.

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<sup>6</sup> The Project for Capacity Development on Climate Change Measure in The Republic of Mauritius (2014-2016)

<sup>7</sup> PDCA (plan-do-check-act or plan-do-check-adjust) an iterative four-step management method used in business for the control and continuous improvement of processes and products. (Rother, Mike (2010). "6". Toyota Kata. New York: McGraw-Hill.)

<sup>8</sup> The Project for Capacity Development on Climate Change Measure in The Republic Of Mauritius



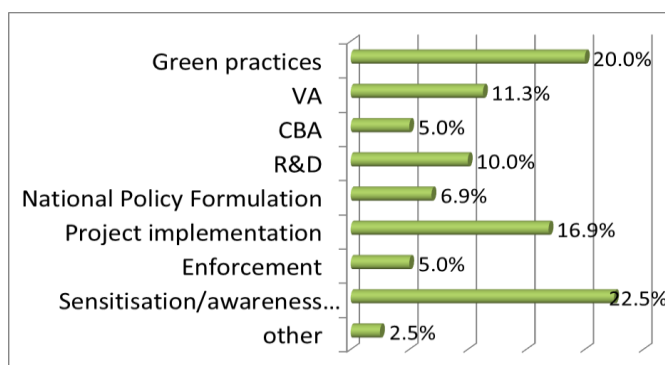


Figure 0.2: Survey Result Sample of Climate Change Activities in Mauritius

The desk study also identified key areas of concern in Mauritius related to the coastal zone such as ecosystem / environmental conservation, coastal infrastructure and coastal zone development. Possibilities for the formulation guidelines considered with coastal infrastructure related to road development, and coastal zone management related to planning guidelines, land use guidelines and building guidelines.

### 1.5 Best Practices on Climate Change Adaptation

For the purpose of this guideline, best practices and experiences on coastal setback from a series of countries facing the adverse impacts of climate change were considered. The approaches adopted coastal setback vary from highly elaborated strategy for countries like USA and Canada supported by latest technology and available data to the establishment of unlegislated 25-meter minimum setback like in the case of Seychelles. Some of the examples of coastal setback are:

**Barbados:** A national statute establishes a minimum building setback along sandy coasts of 30 m from mean high-water mark; along coastal cliffs the setback is 10 m from the undercut portion of the cliff.

**Antigua and Aruba:** Setback established at 50 m inland from high-water mark

**Sri Lanka:** Setback areas and -build zones identified in Coastal Zone Management Plan. Minimum setbacks of 60 m from line of mean sea level are regarded as good planning practice.

**State of Hawaii:** Setback distance is 40ft + (buildings life cycles values X annual erosion rate).

Further details on the experiences of countries considered are at Annex1.

## Methodology

### 1.6 Principles behind the examination the coastal setback

This guideline attempts to make customized reference information base for examination and formulation of site specific coastal setback as a short term countermeasure to address adverse impacts of climate change on the coastal zone of Mauritius. The adoption of risks reduction/mitigation, maintenance of ecosystem integrity and functioning as well as application of precautionary principle is enshrined in the approach. Availability of data was also other prime element in the approach selected.

### 1.7 Data Collection

The core parameters/main elements was discussed and agreed through technical sessions with the concerned stakeholders. Based on the discussion/examination, the data collected/compiled as shown Table 0.1 and Table 0.2

Table 0.1: Collected GIS data: Core Elements/Main Parameters

.	Name	Attribute	Type	Scale/Resolution	Source	Remarks
1	Built-up Area	-	Polygon	1:50,000	MHL	
2	Setback Buffer	-	Polygon	1:50,000		Generated from coastline by GIS
3	Coastal Erosion/Accretion	-	Line	1:50,000	JICA <sup>9</sup>	Extent of the prioritized coastal area
4	Sand Beach and Dune	-	Polygon	1:50,000	ESA <sup>10</sup> , DRR <sup>11</sup>	
5	Mangrove	-	Polygon	1:50,000	ESA	
6	Marshland	Conservation Value	Polygon	1:50,000	ESA	3 classification conservation value (High, Moderate, Low)
7	Cultural and Historical Asset	Name	Point	1:50,000	DRR	Waiting for response of NHF <sup>12</sup>
8	Storm Surge/Coastal Inundation	Hazard Exposure Level	Polygon	1:50,000	DRR	Exposure of storm surge inundation (highest scenario 6m)
9	Coral Reef	-	Polygon	1:50,000	ESA, DRR	
10	Marine Park	Name	Polygon	1:50,000	ESA	
11	National Park	Name	Polygon	1:50,000	ESA	

<sup>9</sup>JICA: The Project for Capacity Development on Coastal Protection and Rehabilitation in the Republic of Mauritius by JICA (Japan International Cooperation Agency), 2015

<sup>10</sup>ESA: Study of Environmentally Sensitive Areas (ESA), Ministry of Environment and National Development Unit, Government of Mauritius, 2009

<sup>11</sup>DRR: Final Report of Disaster Risk Reduction Strategic Framework and Action Plan (DRR) by AAP (African Adaptation Programme), 2012

<sup>12</sup> National Heritage Fund

Table 0.2: Task to be Undertaken and Necessary Information Data

.	Name	Attribute	Type	Scale/Resolution	Source	Remarks
1	Gazetteer	Name	Point	1:50,000	ESA, DRR	
2	Road	Class	Line	1:50,000	ESA, DRR	
4	Stream	Name	Line	1:50,000	ESA, DRR	
5	River	Name, Type	Line	1:50,000	ESA, DRR	
6	Reef	-	Line	1:50,000	ESA, DRR	
8	Islet	Islet Name	Polygon	1:50,000	ESA, DRR	
9	Coast Line	-	Line	1:50,000	ESA, DRR	

## 1.8 Target coastal zones

In line with the findings of the approved “Capacity Development on Coastal Protection and Rehabilitation in the Republic of Mauritius (2015) Report, and discussions with relevant stakeholders, the following thirteen coastal zones were examined

1. Baie du Tombeau;
2. Pointe aux Canoniers;
3. Mon Choisy;
4. Bras d’Eau;
5. Quatre Cocos (Verger) and Trou d’Eau Douce;
6. Ile aux Cerfs;
7. Pointe d’Esny;
8. Bel Ombre;
9. Le Morne;
10. Flic en Flac;
11. Albion;
12. Pointe aux Sables; and
13. Grand Sable.

These sites were identified under the JICA<sup>13</sup> / GOM project having long term erosional characteristics and which are vulnerable to the adverse impacts of climate change.

<sup>13</sup> The Project for Capacity Development on Coastal Protection and Rehabilitation in the Republic of Mauritius by JICA (Japan International Cooperation Agency), 2015

### 1.9 Geo-spatial approach/analysis

A GIS based approach was considered to be most appropriate for examining the coastal setback. The core elements and the main parameters include: physical layers such as land-use, buildings, topography, infrastructure, natural environment and others, and non-physical layers such as population, industry, economy, existing situation/awareness of the community and others. Additionally, the following information were also used for the geo-spatial approach/analysis:

- Storm surge and coastal inundation hazards and risks;
- Coastal erosion (observed over long period based on the site hydrodynamics and presence of passes; erosion post extreme climatic events)
- Presence of environmental sensitive ecosystems (existence of ESAs such as sand beach/dune, marshland, mangrove and marine park);
- Projected sea level rise; and
- Presence of any historical/ cultural and other features of socio economic importance.

The conceptual diagram for the methodology using geo-spatial approach is shown in the. Figure 0.1 below.

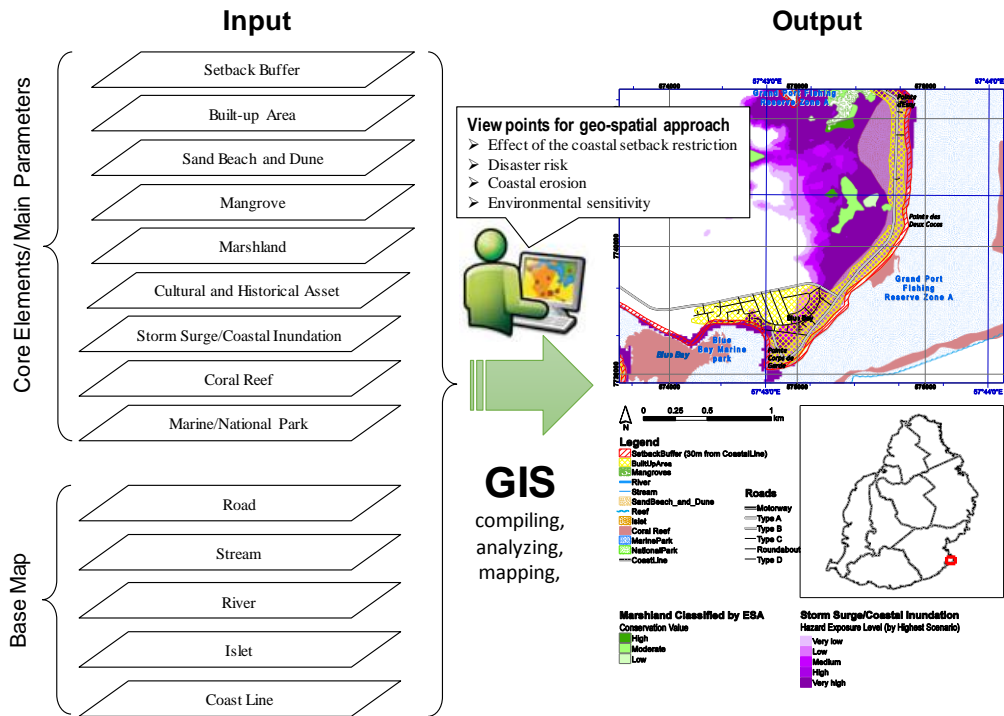


Figure 0.1: Conceptual Diagram of the Methodology (Geo-Spatial Approach)

## 1.10 Setback distance calculation

This section attempt to consider a conceptual calculation approach (amount of setback) using examples from the existing project<sup>14</sup>.

### 1.10.1 Sandy and/ or a mixed beach type

The setback amount for sand beaches and/ or a mixed beaches type is configured as summation of the amount of erosion which occurred during a certain period (between 20 and 30 years), the amount of erosion/ extent of inundation which was caused by strong storm surges waves run up in that period, the stretch likely to be inundated due to the SLR (sea level rise) as projected in the future, and the width of ESAs and other historical and cultural features., if any.

*Amount of setback = Amount of erosion for a long period + Amount of erosion/ extent of inundation caused by temporary event (i.e. extreme weather conditions such as cyclones ) + Erosion amount/ stretch likely to be inundated due to SLR + width of ESA, if any on the site including appropriate buffer + distance to cater for cultural/ historical and other features of socio economic importance, if any*

It is to be noted that for the purpose of determining the minimum setback, the inundation hazard due to a wave height of 2.5m was used. This assumption figure of 2.5 m wave height will also account for (i) a SLR of the order of 1m projected for in 2100; (ii) a tidal range of 0.5 m, and (iii) a wave run up of 1 m which is likely to happen during an extreme weather event (Figure 0.2)

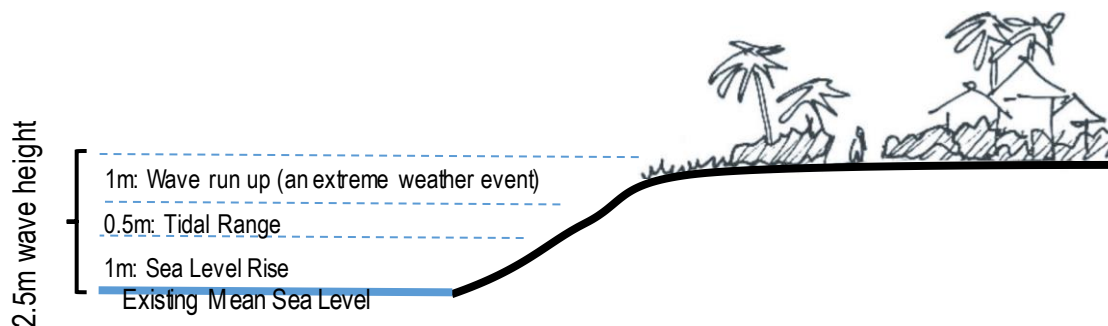


Figure 0.2: Assumption of a Wave Height

<sup>14</sup>The Project for Capacity Development on Coastal Protection and Rehabilitation in the Republic of Mauritius by JICA (Japan International Cooperation Agency), 2015



Cyclone Carol caused extensive damage in Mauritius in 1960. Wave run up identified on the shoreline by field survey, erosion situation and observation record at that time are recorded in Tropical Cyclones and Coastal Morphology in Mauritius. Figure 0.5 shows the height of waves observed at that point in time. The maximum of wave run up was 12 feet (about 3.65 m). Therefore the above assumption of a wave run up of 1m during extreme weather events is reasonable.

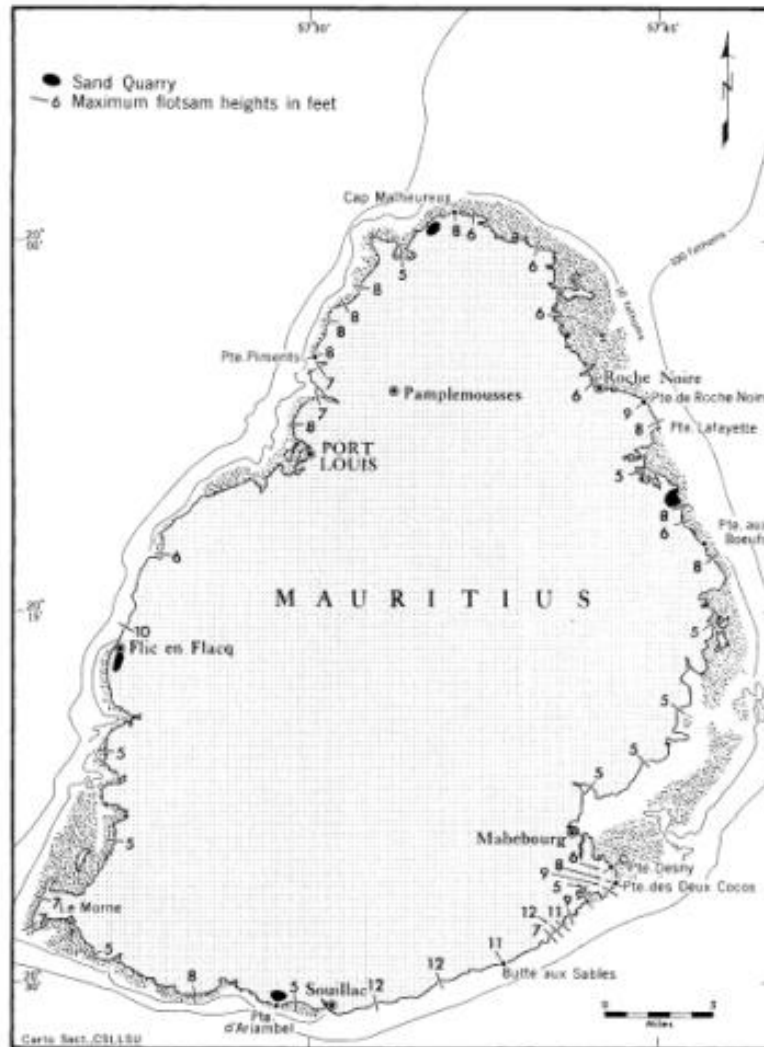


Figure 0.5: Wave Rising Elevation of Cyclone Carol (unit:feet)<sup>16</sup>

<sup>16</sup> Tropical Cyclones and Coastal Morphology in Mauritius

Figure 0.6 shows aerial and satellite photographs taken in 1967 and 2008, Mon Choisy. The shoreline positions are shown in blue (1967) and red (2008). The shoreline at south of the public beach was eroded 12m on average and 18m at the maximum within 45 years since 1967. The erosion seems to be continuing at present. The rate of erosion is between 0.3m/year and 0.45m/year. The proposed calculation of amount of setback in this section accounts for the amount of erosion for a long period which is shown on below.

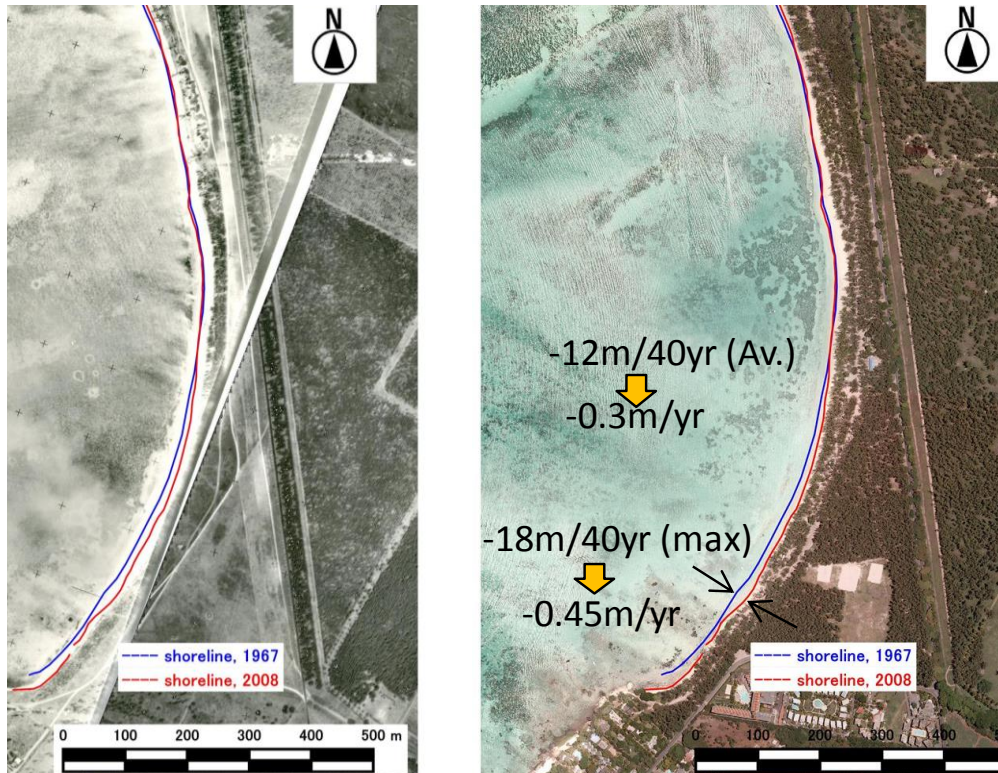


Figure 0.6: Comparison of Aerial Photo (Eroded south area), left: 1967, right: 2008<sup>17</sup>

<sup>17</sup> Processed by The Project for Capacity Development on Coastal Protection and Rehabilitation (JICA , 2015) based on aerial photo and satellite image obtained from MHL



### 1.10.2 Cliff coast (case example: cliffy part in Albion)

The setback line will be determined considering the estimation of cliff erosion speed, the life time of houses or structures, the slope area of the cliff and horizontal area. The most important is the slope area and it should be analysed based on the site inspection and aerial photos. From the preliminary site investigation, two areas can be taken as shown in. The first is the slope area where the rock is weathered and the cave is formed. The second is the horizontal area where estimated from the slope stability.

Inclined area is dangerous and sufficient setback line (H=20m) should be secured.

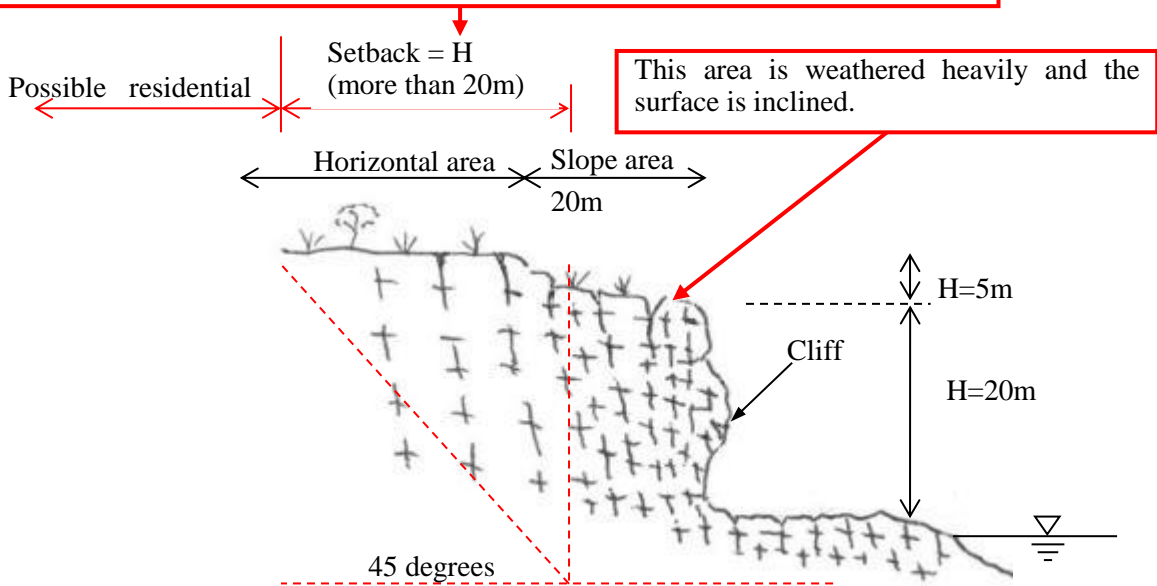


Figure0.7: Image of the Setback Line

Based on the site inspection results, a preliminary examination of the setback line was conducted considering the facts that the existing cliff has been weathered, forming some caves, and the maximum stable degree (45 degree). A supplemental investigation will be conducted to analyze the existing conditions in details and then the final setback line will be determined. Figure2.2 above illustrates the image of the setback line.

Plateau behind coastal cliff behind has been used as a residential area and sugar cane fields mainly. There is a plan for future development in the hinterland at the area of lighthouse. The setback line of important public facilities has to be decided in considering the long term cliff erosion and corruption. The long term erosion is estimated 5 m if the erosion speed is assumed as 5cm/year of basalt from experience and 100 years of service period. It is better to use 5cm /year as an example. Further investigations required for Mauritius, to define parameters required-to elaborate. Then the setback line becomes as follows.

**Minimum Setback Line** = Slope Area + Horizontal Area + 5 m + width of ESA, if any on the site including appropriate buffer + distance to cater for cultural/ historical and other features of socio economic importance, if any.

The minimum setback is estimated from the limited information at present. It becomes 65 m in

total if the slope area is 30 m, the horizontal area is 30 m of 30 m high cliff and erosion is 5 m. It is comparable to the Pas Geometriques of 81 m if a margin is considered.

The actual figure can be decided from the precise topographic map. At present the contour interval of the map is 10 m in Mauritius. It is difficult to estimate the ground height of the cliff and the survey is necessary along the coast.

### **1.10.3 Basic concept/approach to examine the setback distance (Balancing between disaster/environment risk and realities)**

From view point of the disaster/environment risk consideration, hazard exposure level of storm surge/inundation stretches several tens of meters to hundreds meters from shoreline. And, the shoreline have been fluctuating several meters to tens of meters by erosion. ESAs are distributed several meters to hundreds meters from shoreline.

On the other hand, from view point of the real situation, the built-up areas have been existing from shoreline to hundreds meters. Additionally, the sustainable development, effect to the economy/industry, impact to the local community, historical/cultural assets and others have to be considered.

Based on the above, in the next chapter, target coastal zones were examined from view point of balancing between disaster/environment risk and realities. In particular, the shortest distance from shoreline in distributions of storm surge/inundation hazard, erosion, ESAs and historical/cultural assets are considered as a safe setback and reasonable for future development.

## Findings: Estimated coastal setbacks for selected areas around Mauritius (short term countermeasure)

### 1.11 Baie du Tombeau

Figure 0.1 below shows an example of a map of Baie du Tombeau area with reference information for the examination of coastal setback in that area.

- Spatial analysis shows that the coastline consists of built up areas up to the high water mark with the exception of the middle southern part (about 1 km stretch). It is observed that no coastal setback as imposed by the PPG has been complied with.
- Storm surge/coastal inundation<sup>18</sup>: Hazard exposure level may cover a width ranging minimum about 50 m (surges in the lagoon would be 2.5 m wave height) to maximum 600 m (surges in the lagoon would be 6 m wave height) from shoreline.
- According to the existing study, the site characteristics with regard to erosion are as follows:
  - Erosion Category: Partial Erosion
  - Yearly Sediment Budget (m<sup>3</sup>/year): 390
  - Category of Sediment Budget: Balanced
- Environmental Sensitive Area (ESA): There is no coastal marshland, no mangrove and no national/marine park along that stretch.

Based on the above observation: a safe setback at least 50 m (depending on site location) could be considered as reasonable for future development

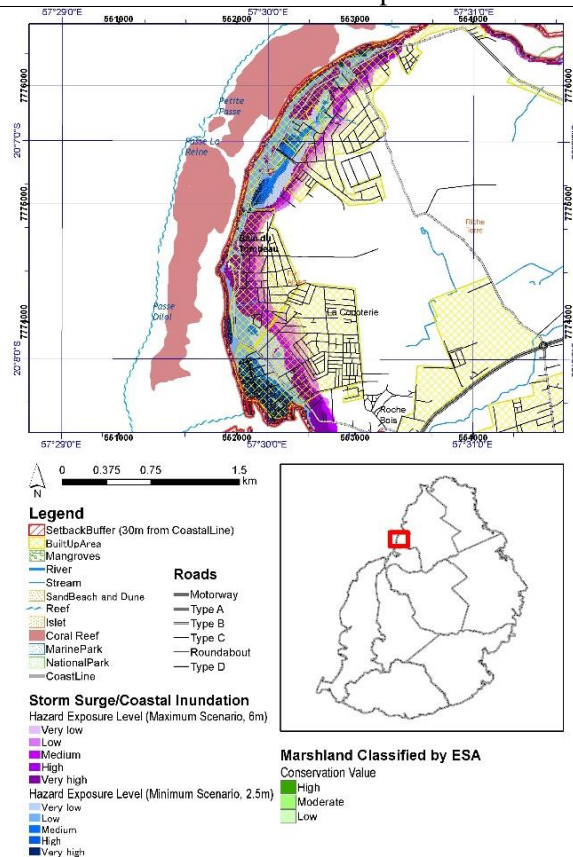


Figure 0.1: Sample Map for Coastal Setback Examination - Baie du Tombeau

<sup>18</sup> Based on the DRR, the minimum surges in the lagoon would be 2.5 m wave height, and maximum surges in the lagoon would be 6 m. This assumption is used for the all maps/considerations of storm surge/coastal inundation in this chapter.

## 1.12 Pointe aux Canonniers

Figure 0.2 below shows an example of a map of Pointe aux Canonniers area with reference information for the examination of coastal setback. It is observed that:

- Built-up areas are located within the 30 m from high water mark line in the northern part of the coastline. The setback imposed under the PPG is partially complied with. On the eastern side, most of the built-up areas encroach within the 30 m setback zone.
- Storm surge/coastal inundation: Hazard exposure level may cover a width ranging about 50 m to 800 m from shoreline.
- According to the existing study, the nature of erosion along this stretch is characterized as follows:
  - Erosion Category: Erosion
  - Yearly Sediment Budget (m<sup>3</sup>/year): -50
  - Category of Sediment Budget: Decrease
- Environmental Sensitive Area (ESA): There is no coastal marshland, no mangrove and no national/marine park. Sand beach and dune cover in most parts of this area.

Based on the above observation: a safe setback at least 50 m (depending on site location) could be considered as reasonable for future development

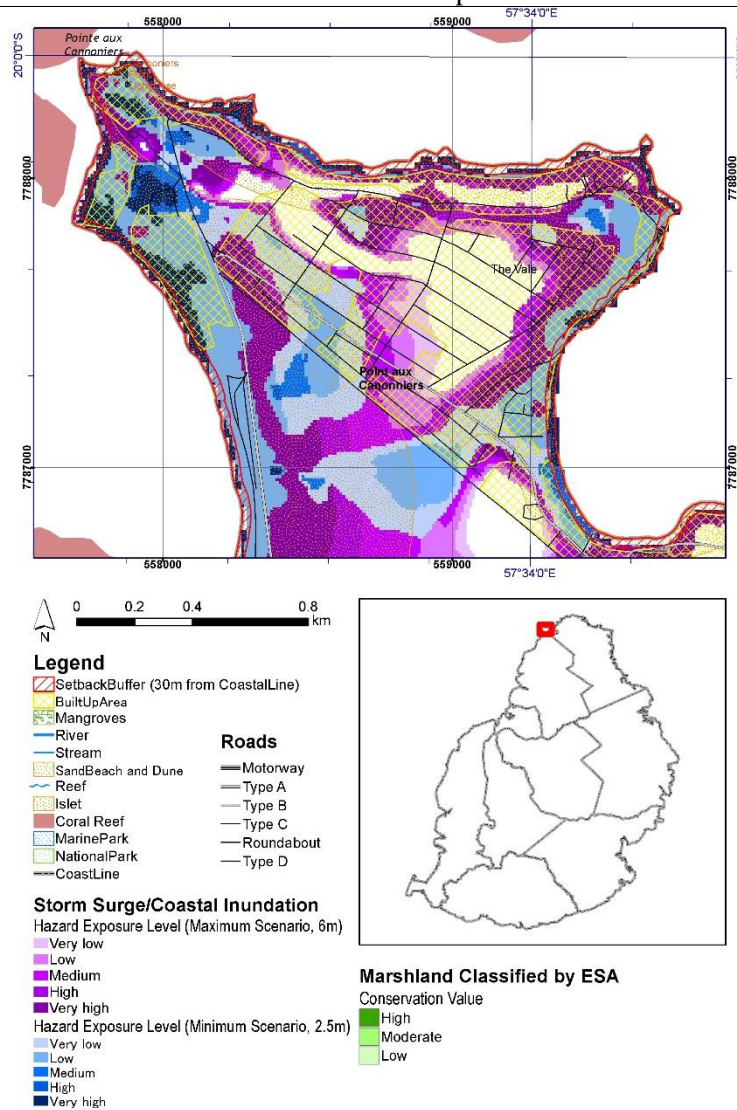


Figure 0.2: Sample Map for Coastal Setback Examination - Pointe aux Canonniers

### 1.13 Mon Choisy

Figure 0.3 below shows an example of a map with reference information for the examination coastal setback in Mon Choisy area. It is observed that:

- The coastal setback of 30 m and built-up areas do not intercept in the northern part of the coastline implying compliance to the PPG.
- Storm surge/coastal inundation: Hazard exposure level may cover a width ranging minimum 40 m to about 800 m from shoreline.
- According to the existing study, the nature of erosion along this stretch is characterized as follows:
  - Erosion Category: Erosion
  - Yearly Sediment Budget (m<sup>3</sup>/year): -500
  - Category of Sediment Budget: Decrease
- Environmental Sensitive Area (ESA): There is no marshland, no mangrove and no national/marine park. Sand beach and dune cover in most parts of this area.

Based on the above observation: a safe setback at least 40 m (depending on site location) could be considered as reasonable for future development

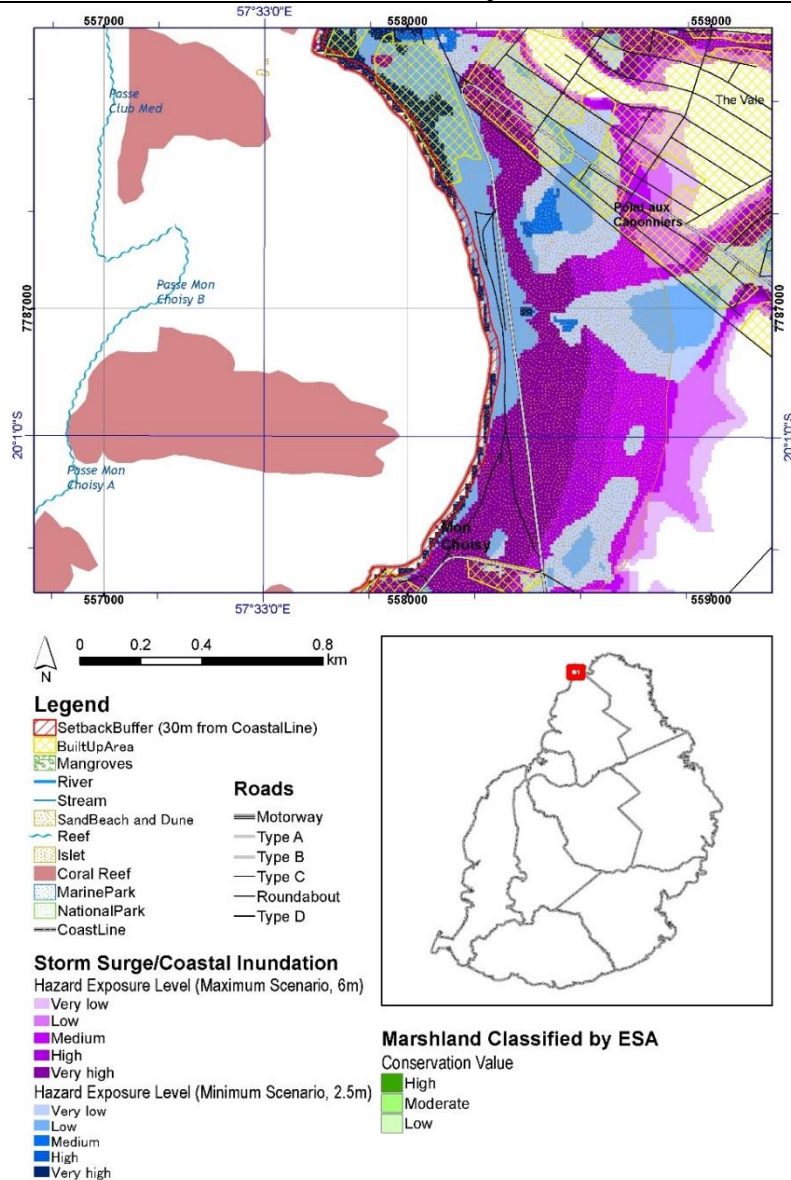


Figure 0.3: Sample Map for Coastal Setback Examination - Mon Choisy

### 1.14 Bras d'Eau

Figure 0.4 below shows an example map with reference information for the examination of coastal setback in Bras d'Eau coastal area. It is observed that:

- The built-up areas do not encroach with PPG setback in this area. It seems that the setback regulation is functioning appropriately in this area.
- Storm surge/coastal inundation: Hazard exposure level may cover a width ranging about 30 m to 700 m from shoreline.
- According to the existing study, the nature of erosion along this stretch is characterized as follows:
  - Erosion Category: Partial Erosion
  - Yearly Sediment Budget (m<sup>3</sup>/year): 210
  - Category of Sediment Budget: Balanced
- Environmental Sensitive Area (ESA): There are two coastal marshlands, Poste La Fayette Fishing Reserve and mangroves (in southern part). Sand beach and dune cover in most parts of this area.

Based on the above observation: a safe setback at least 30 m (depending on site location) could be considered as reasonable for future development

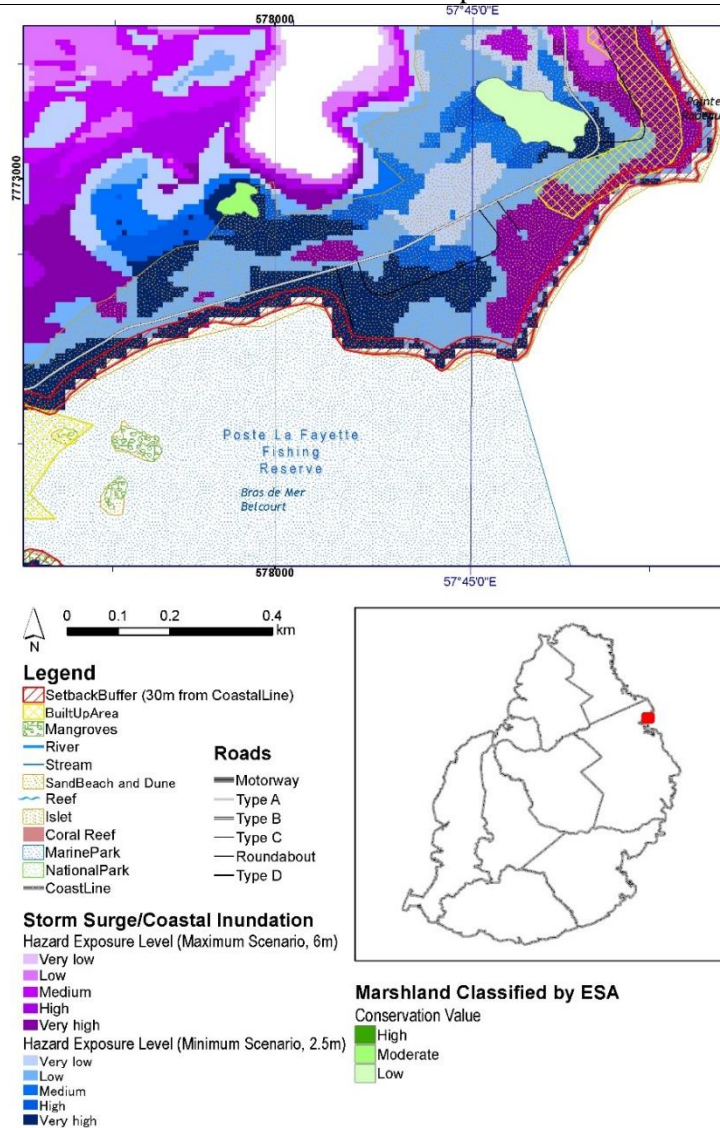


Figure 0.4: Sample Map for Coastal Setback Examination - Bras d'Eau

### 1.15 Quatre Cocos (Verger) and Trou d'Eau Douce

Figure 0.5 below shows an example of a map with reference information for the examination of coastal setback in Quatre Cocos (Verger) and Trou d'Eau Douce. It is observed that:

- Most of the built-up areas are located within 30 m from the High Water Mark.
- Storm surge/coastal inundation: Hazard exposure level may cover a width ranging about 40 m to 600 m from shoreline.
- According to the existing study, the nature of erosion along this stretch is characterized as follows:
  - Erosion Category: Partial Erosion
  - Yearly Sediment Budget (m<sup>3</sup>/year): 400
  - Category of Sediment Budget: Balanced
- Environmental Sensitive Area (ESA): There are nine coastal marshlands, Trou d' Eau Douce Fishing Reserve. Sand beach and dune cover in most parts of this area.

Based on the above observation: a safe setback at least 40 m (depending on site location) could be considered as reasonable for future development

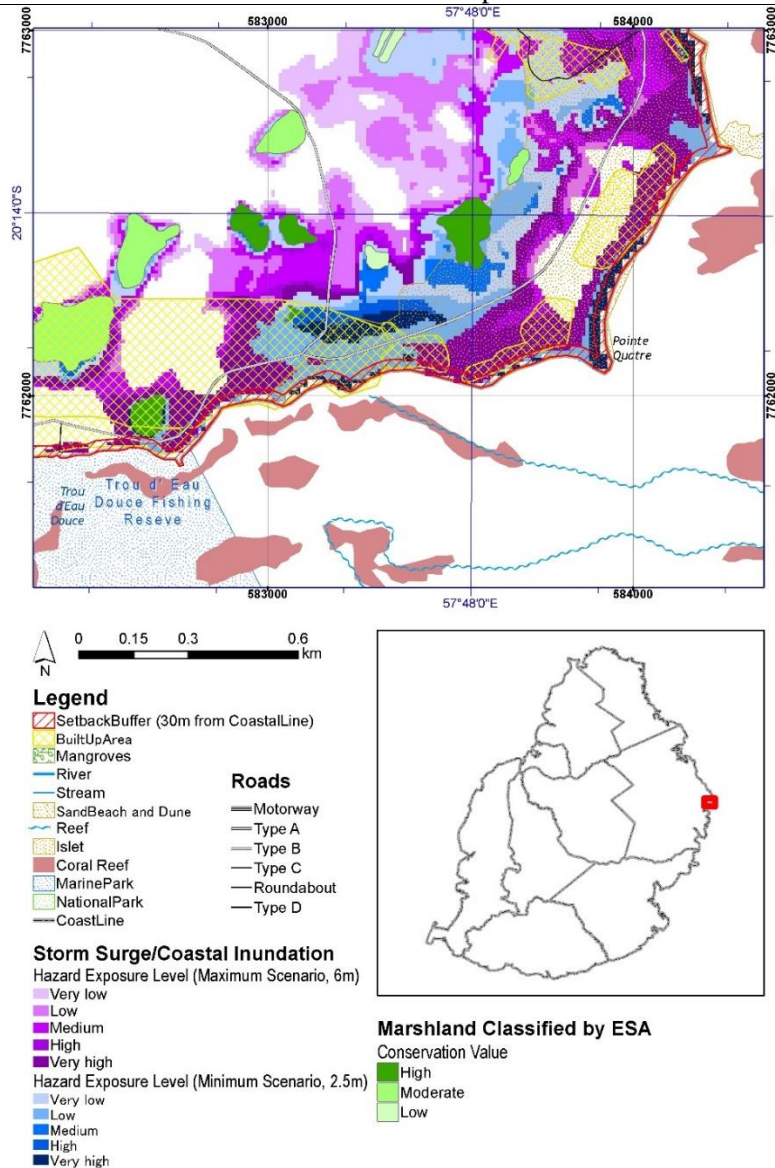


Figure 0.5: Sample Map for Coastal Setback Examination - Quatre Cocos (Verger) and Trou d'Eau Douce

### 1.16 Ile aux Cerfs

Figure 0.6 below shows an example of a map with reference information for the examination of coastal setback in Ile aux Cerfs. It is observed that:

- The built up areas do not encroach within the 30 m from the High Water Mark.
- Storm surge/coastal inundation: Most of this area may be covered by highest hazard exposure level.
- According to the existing study, the nature of erosion along this stretch is characterized as follows:
  - Erosion Category: Sedimentation
  - Yearly Sediment Budget (m<sup>3</sup>/year): 3,610
  - Category of Sediment Budget: Increase
- Environmental Sensitive Area (ESA): There are mangroves, Trou d' Eau Douce Fishing Reserve. Sand beach and dune cover in most parts of this area.

On account of the above observations, low lying nature of the islet, high inundation hazard risk and as a safety measure it is suggested that only climate resilient measures and activities be considered in future development.

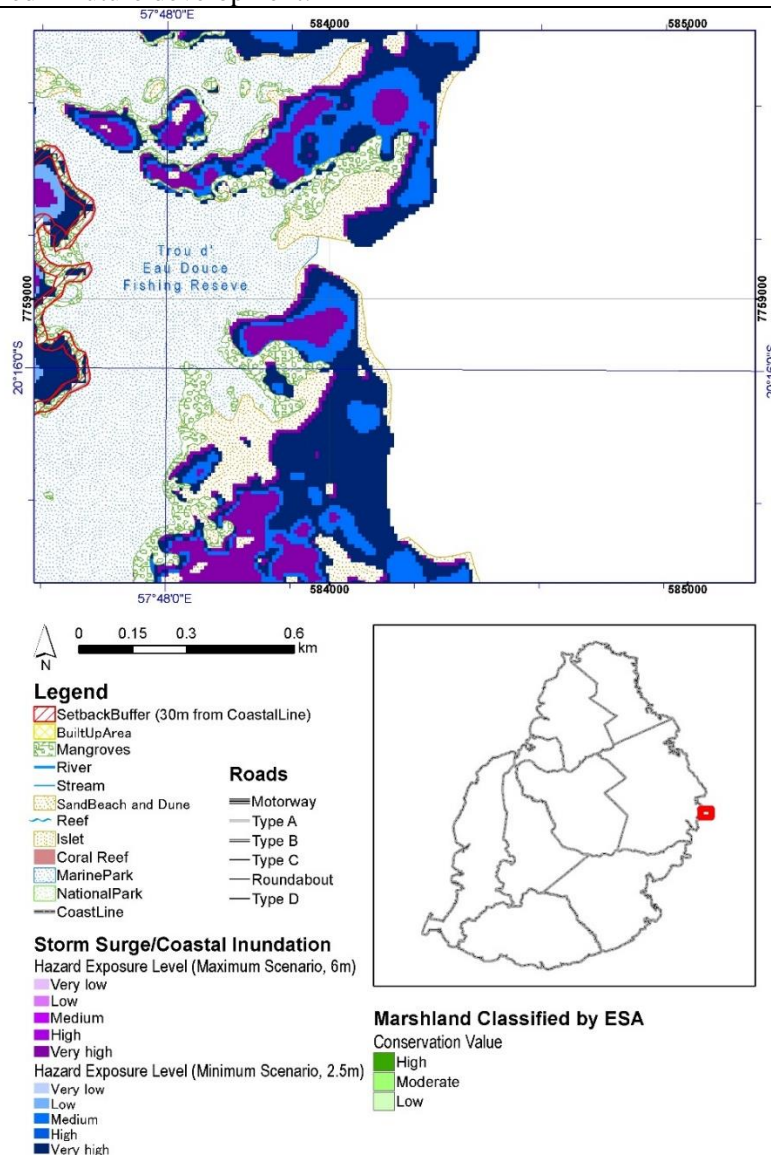


Figure 0.6: Sample Map for Coastal Setback Examination - Ile aux Cerfs



### 1.17 Pointe d'Esny

Figure 0.7 shows an example of a map with reference information for the examination of coastal setback in Pointe d'Esny. It is observed that:

- Most built-up areas are outside the 30 m setback. However, in the southern part there are built-up areas within the 30 m setback.
- Storm surge/coastal inundation: Hazard exposure level may cover a width ranging about 30 m to 1,300 m from shoreline.
- According to the existing study, the nature of erosion along this stretch is characterized as follows:
  - Erosion Category: Partial Erosion
  - Yearly Sediment Budget (m<sup>3</sup>/year): 390
  - Category of Sediment Budget: Balanced
- Environmental Sensitive Area (ESA): There are coastal marshlands (from the eastern to northern part of the shoreline), mangroves (in northern part), Grand Port Fishing Reserve Zone A and the Blue Bay Marine Park. Sand beach and dune cover the eastern part of the coastline.

Based on the above observations, a safe setback at least 30 m (depending on site location) could be considered as reasonable for future development

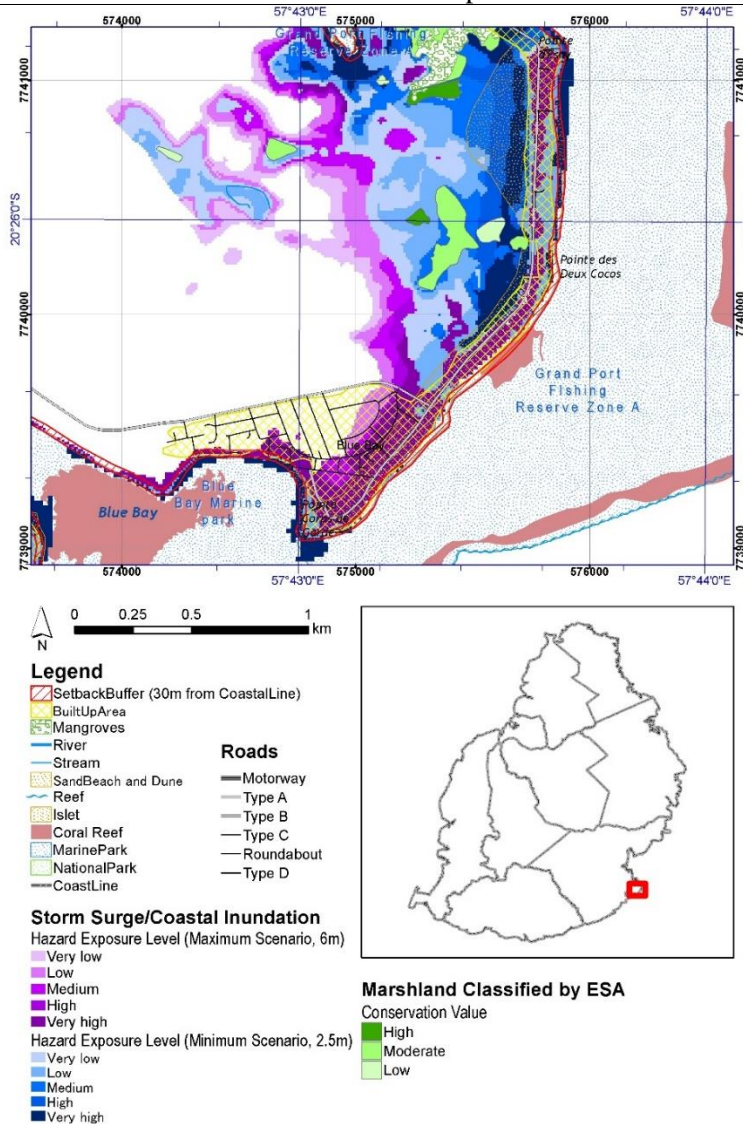


Figure 0.7: Sample Map for Coastal Setback Examination - Pointe d'Esny

### 1.18 Bel Ombre

Figure 0.8 below shows an example of a map with reference information for the examination of coastal setback in Bel Ombre. It is observed that:

- Most built up areas are outside the 0 to 30 m zone. However, there is a slight overlap of the built up areas with the 30 m coastal setback buffer zone in the western part of the shoreline.
- Storm surge/coastal inundation: Hazard exposure level may cover a width ranging about 50 m to 1,000 m from shoreline.
- According to the existing study, the nature of erosion along this stretch is characterized as follows:
  - Erosion Category: Partial Erosion
  - Yearly Sediment Budget (m<sup>3</sup>/year): 1410
  - Category of Sediment Budget: Increase
- Environmental Sensitive Area (ESA): There are coastal marshlands (in the western and eastern part of the shoreline), mangroves (in western part of shoreline), Sand beach and dune cover in most parts of this area.

Based on the above observation: a safe setback at least 50 m (depending on site location) could be considered as reasonable for future development

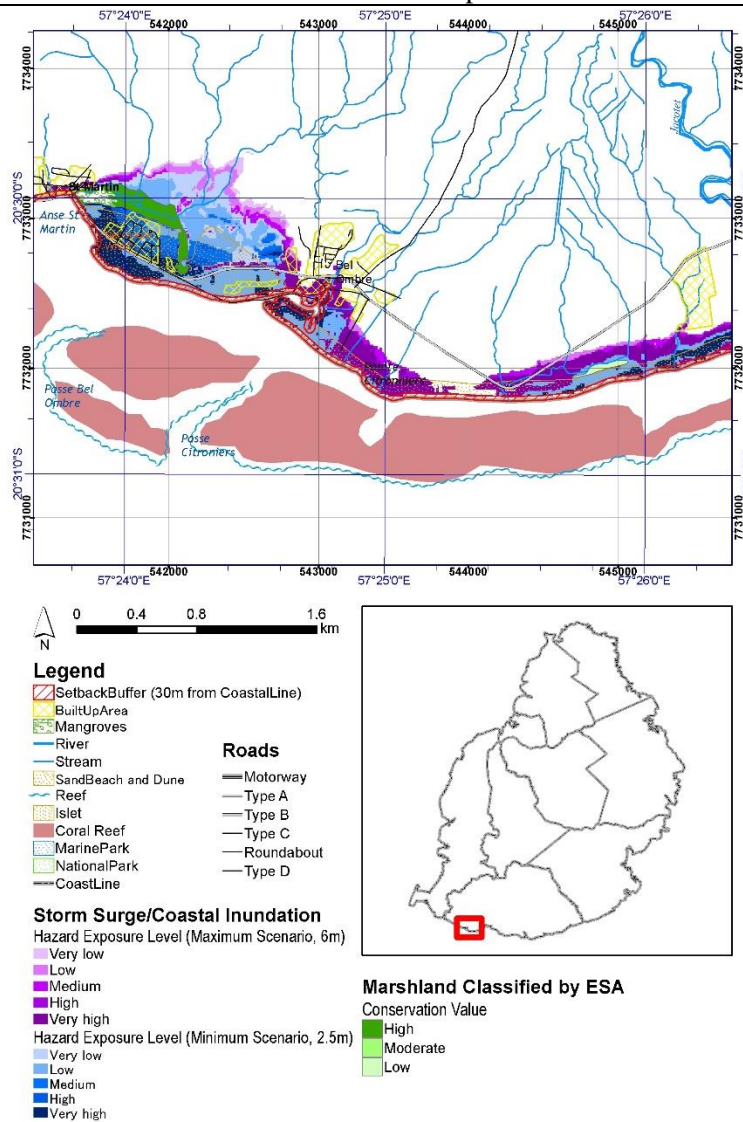


Figure 0.8: Sample Map for Coastal Setback Examination - Bel Ombre

### 1.19 Le Morne

Figure 0.9 below shows an example of a map with reference information for the examination of coastal setback in Le Morne. It is observed that:

- The north western part of the shoreline, there is a slight encroachment of built up areas with the 30 m coastal setback buffer zone.
- Storm surge/coastal inundation: Hazard exposure level may cover a width ranging about 60 m to 500 m from shoreline.
- According to the existing study, the nature of erosion along this stretch is characterized as follows:
  - Erosion Category: Partial Erosion
  - Yearly Sediment Budget (m<sup>3</sup>/year): 1,240
  - Category of Sediment Budget: Increase
- Environmental Sensitive Area (ESA): Sand beach and dune cover the western part of the coastline.
- Cultural/Historical Assets: There is the Le Morne Brabant as UNESCO World Heritage Site.

Based on the above observation: a safe setback at least 60 m (depending on site location) could be considered as reasonable for future development

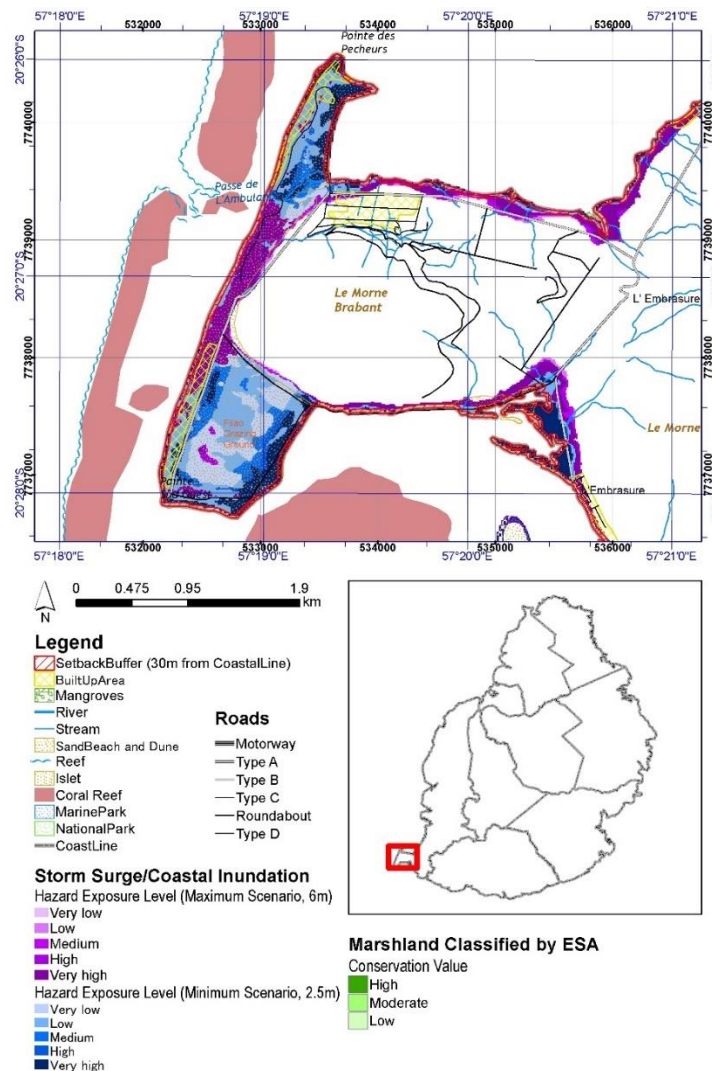


Figure 0.9: Sample Map for Coastal Setback Examination -Le Morne

## 1.20 Flic en Flac

Figure 0.10 below shows an example of a map with reference information for the examination of coastal setback in Flic en Flac. It is observed that:

- Most built up areas along the shoreline are outside the coastal setback of 30 m from the High Water Mark. There is a slight encroachment of built up areas on the 30m setback in the southern part of the shoreline.
- Storm surge/coastal inundation: Hazard exposure level may cover a width ranging about 30 m to 1,000 m from shoreline.
- According to the existing study, the nature of erosion along this stretch is characterized as follows:
  - Erosion Category: Partial Erosion
  - Yearly Sediment Budget (m<sup>3</sup>/year): 530
  - Category of Sediment Budget: Balanced
- Environmental Sensitive Area (ESA): There are coastal marshlands (in southern part of the shoreline), Sand beach and dune cover in most parts of this area.

Based on the above observation: a safe setback at least 30 m (depending on site location) could be considered as reasonable for future development

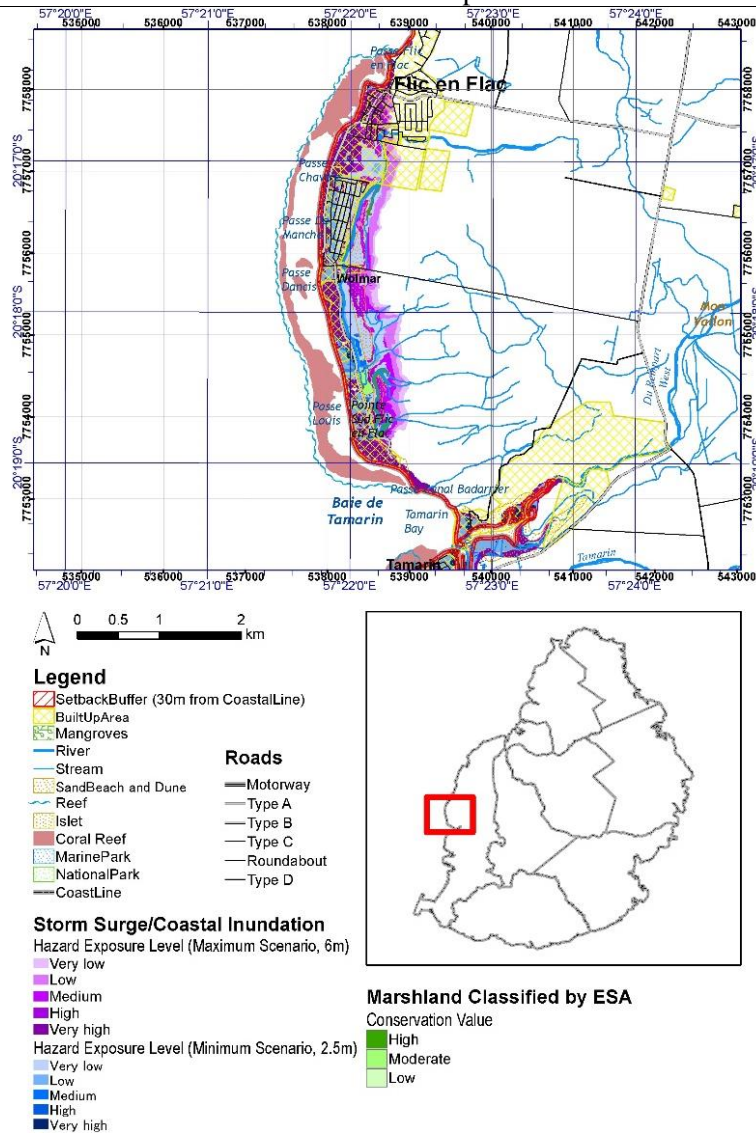


Figure 0.10: Sample Map for Coastal Setback Examination - Flic en Flac

### 1.21 Albion

Figure 0.11 below shows an example of a map with reference information for the examination of coastal setback in Albion. It is observed that:

- Built up areas are located within 30m from the High Water Mark in the northern and southern parts of the shoreline.
- Storm surge/coastal inundation: Hazard exposure level may cover a width ranging about 30 m to 600 m from shoreline.
- According to the existing study, the nature of erosion along this stretch is characterized as follows:
  - Erosion Category: Erosion
  - Yearly Sediment Budget (m<sup>3</sup>/year): -170
  - Category of Sediment Budget: Decrease
- Environmental Sensitive Area (ESA): Sand beach and dune cover in most parts of this area.

Based on the above observation: a safe setback at least 30 m (depending on site location) could be considered as reasonable for future development

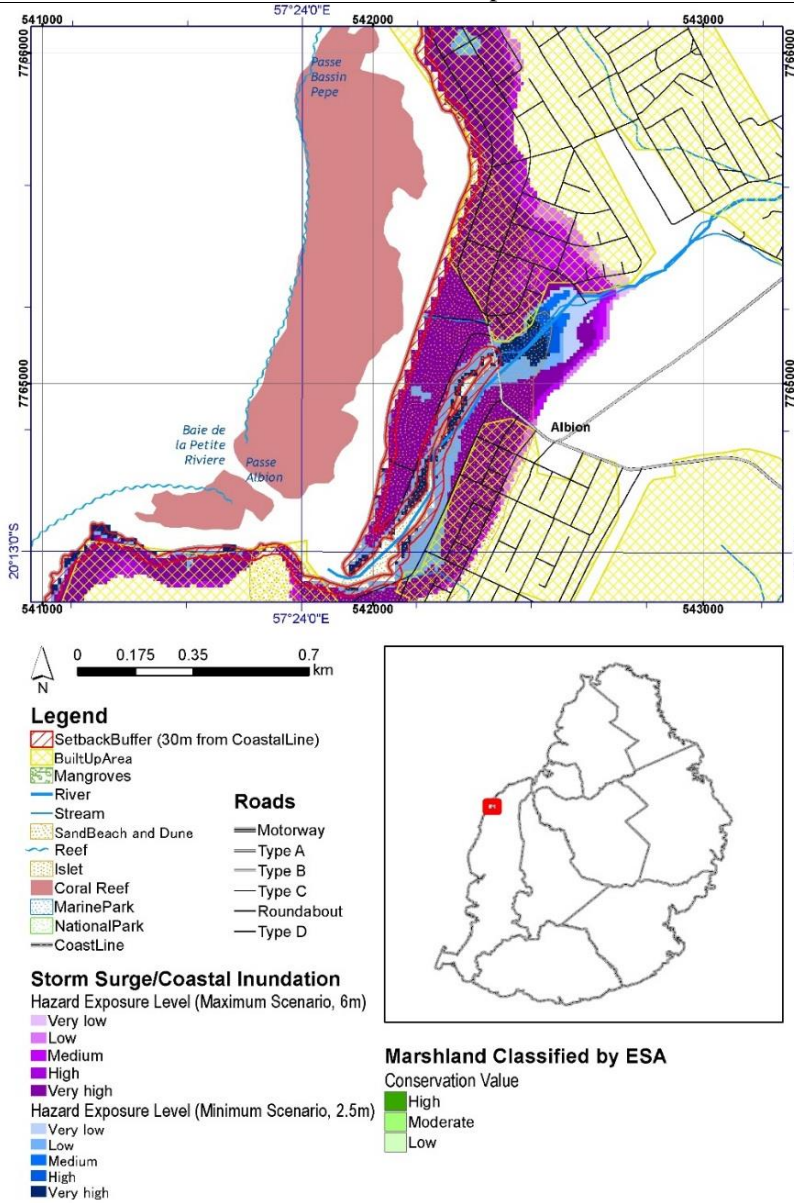


Figure 0.11: Sample Map for Coastal Setback Examination - Albion

## 1.22 Pointe aux Sables

Figure 0.12 below shows an example of a map with reference information for the examination of coastal setback in Pointe aux Sables. It is observed that:

- Built up areas are within the 30 m from the HWM in the western part of the shoreline.
- Storm surge/coastal inundation: Hazard exposure level may cover a width ranging about 30 m to 400 m from shoreline.
- According to the existing study, the nature of erosion along this stretch is characterized as follows:
  - Erosion Category: Partial Erosion
  - Yearly Sediment Budget (m<sup>3</sup>/year): 1,200
  - Category of Sediment Budget: Increase
- Environmental Sensitive Area (ESA): There is Port Louis Fishing Reserve. Sand beach and dune cover the north coastline of this area.

Based on the above observation: a safe setback at least 30 m (depending on site location) could be considered as reasonable for future development

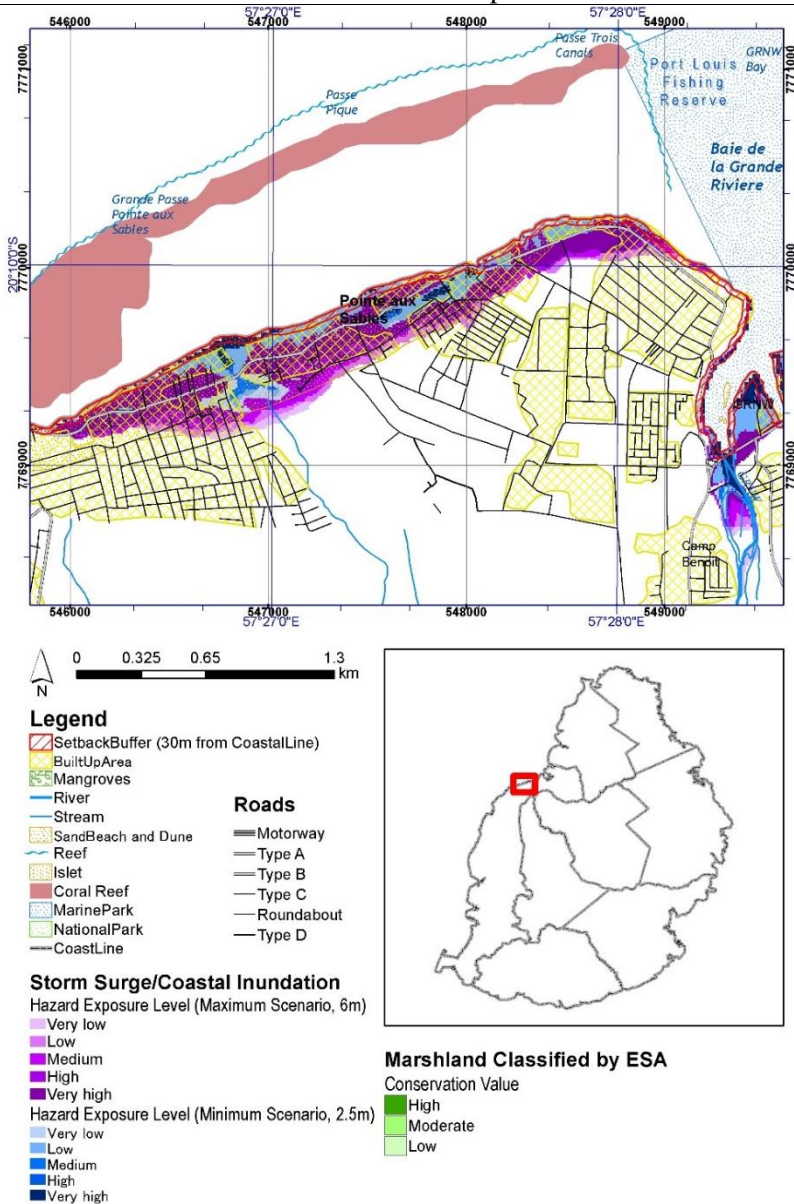


Figure 0.12: Sample Map for Coastal Setback Examination - Pointe aux Sables

### 1.23 Grand Sable

Figure 0.13 below shows an example of a map with reference information for the examination of coastal setback in Grand Sable. It is observed that:

- Most built up areas are within 30m from the HWM along the shoreline.
- Storm surge/coastal inundation: Hazard exposure level may cover a width ranging about 30 m to 400 m from shoreline.
- Environmental Sensitive Area (ESA): There are mangroves in the middle-eastern part of the coastline.

Based on the above observation: a safe setback at least 30 m (depending on site location) could be considered as reasonable for future development

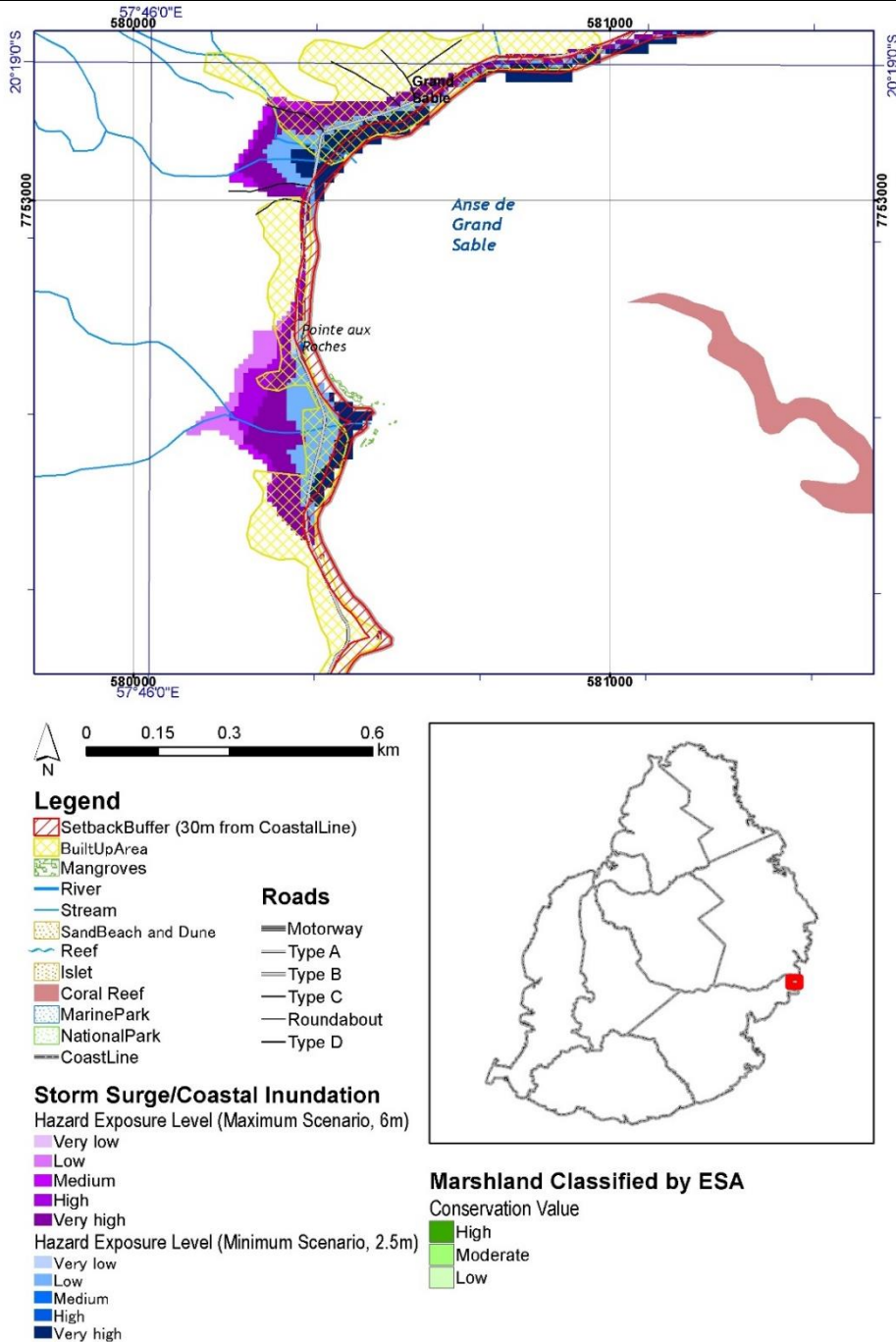


Figure 0.13: Sample Map for Coastal Setback Examination - Grand Sable

## Way forward/Recommendation: Action plan for refining the coastal setback as a mid-long term countermeasure

### 1.24 Basic concept of the action plan

Figure 0.1 shows a conceptual image of the action plan for coastal setback which is composed of two elements; time schedule and PDCA cycle. The time schedule shows the main points/objectives of each year. The PDCA cycle part has vertical and horizontal axis. The former indicates width of the effort for the setback. The latter is an indicator for the time and achievement level for the climate change adaptation. Based on the PDCA cycle, the activities can be well-rounded. And, accumulation of the activities can be contributed to the achievement of climate change adaptation.

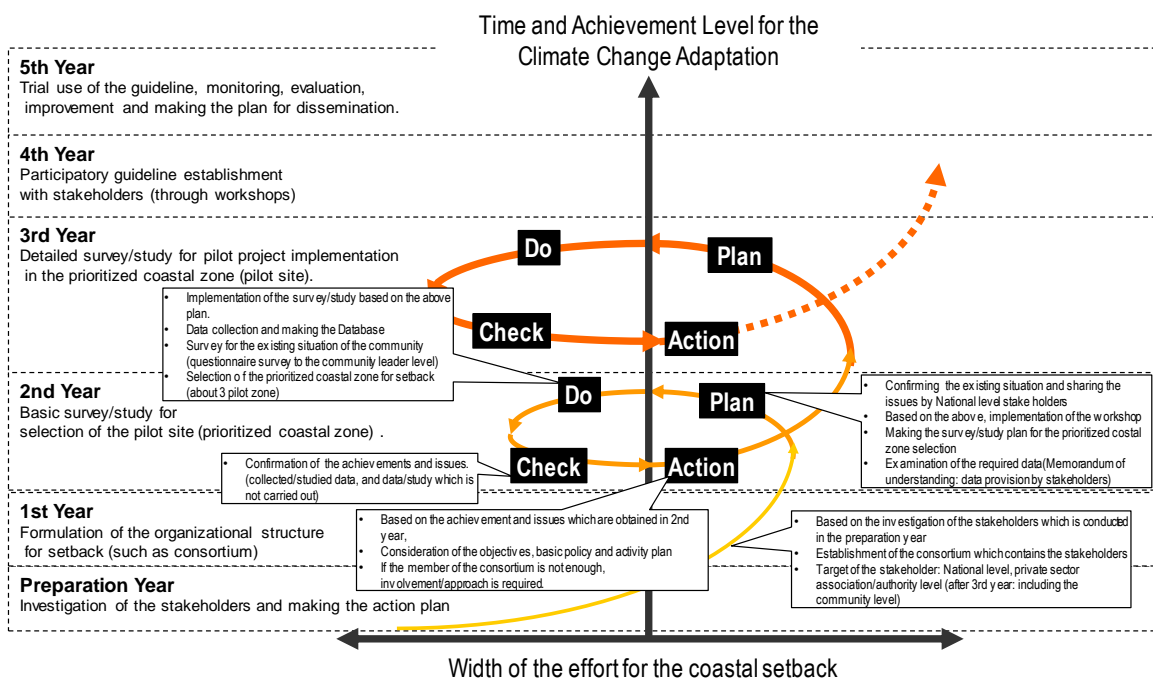


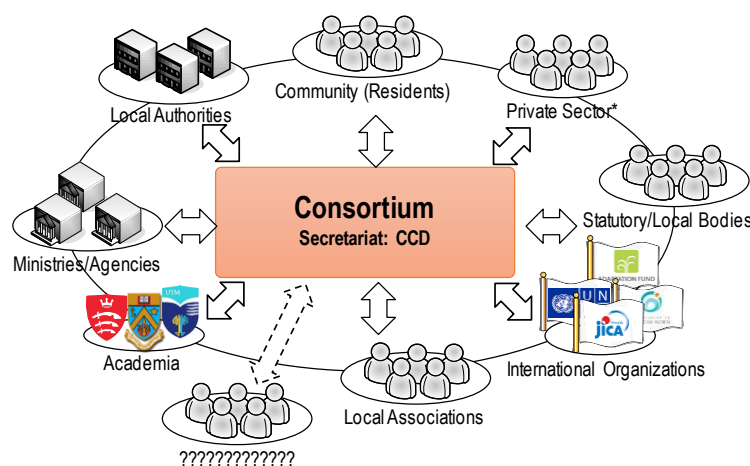
Figure 0.1: Conceptual Image of the Action Plan for Refining of the Setback

The time schedule is a five year plan which includes the followings;

- Preparation Year: Investigation of the stakeholders and making the action plan
- 1st Year: Formulation of the organizational structure for coastal setback (such as consortium)
- 2nd Year: Basic survey/study for selection of the pilot site (prioritized coastal zone)
- 3rd Year: Detailed survey/study for pilot project implementation in the prioritized coastal zone (pilot site).
- 4th Year: Participatory guideline establishment with stakeholders (through workshops)
- 5th Year: Trial use of the guideline, monitoring, evaluation, improvement and making the plan for dissemination.

First of all, the formulation of the organizational structure for coastal setback such as a public-private consortium is required to promote the activities. Figure 0.2 shows an image of the composition of the public-private consortium. The related organizations such as Ministries/Agencies, Local Associations, International Organizations, Academia, Statutory/Local Bodies, Private Sector, Local Authorities should be involved in the consortium. Even though the involvement is not enough in the initial phase, the continuous approach to the related organization is required to obtain the participation from the middle of the activities.





\* Examples of private sector: fishery cooperative, building contractors association, architects association, real estate companies association, developer association, travel agents association etc.

Figure 0.2: Image of the Composition of the Consortium

### 1.25 Prioritization of coastal zone from coastal setback viewpoint

In the second year, a reference information for prioritization of the coastal zone will be required. Table 0.1 shows an example of reference information for prioritization of the coastal zone. It contains two types of information which are physical (such as land-use, buildings, topography, infrastructure, natural environment and others) and n-physical (such as population, industry, economy, existing situation/awareness of the community and others). When the basic policy of the coastal setback will be considered/examined, the reference information will be utilized. The addition of the data or update will be required through the discussion of the consortium. Based on the information, a methodology for decision support is also required such as ISM<sup>19</sup>, AHP<sup>20</sup>, DEMATEL<sup>21</sup>, combination of these methodology<sup>22</sup> and others.

<sup>19</sup> Interpretive structural modelling (ISM) is a well-established methodology for identifying relationships among specific items, which define a problem or an issue. This approach has been increasingly used by various researchers to represent the interrelationships among various elements related to the issue. ISM approach starts with an identification of variables, which are relevant to the problem or issue. (Rajesh Attri et al.; Interpretive Structural Modelling (ISM) approach: An Overview (2013), Research Journal of Management Sciences)

<sup>20</sup> The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. It has particular application in group decision making. (Saaty, et al. (2008). Group Decision Making: Drawing out and Reconciling Differences. Pittsburgh, Pennsylvania: RWS Publications.) and is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, shipbuilding and education. (Saracoglu, B.O. (2013). "Selecting industrial investment locations in master plans of countries". European J. of Industrial Engineering)

<sup>21</sup> Decision-Making Trial and Evaluation Laboratory (DEMATEL) methodology has been proposed to solve complex and intertwined problem groups in many situations such as developing the capabilities, complex group decision making, security problems, marketing approaches, global managers, and control systems. DEMATEL is able to realize casual relationships by dividing important issues into cause and effect group as well as making it possible to visualize the casual relationships of subcriteria and systems in the course of casual diagram that it may demonstrate communication network or a little control relationships between individuals. (ElhamFalatoonitoosiet al. (2014); Expanded DEMATEL for Determining Cause and Effect Group in Bidirectional Relations, The Scientific World Journal).

<sup>22</sup> Example of the combination of the ISM, AHP and DEMATEL to the application for disaster risk management: Yoshimizu GONAI et al. (2007); A Development of Quantitative Evaluation Method for Capability of Community-based Disaster Mitigation Focused on Neighborhood Community Association, City planning review. Special issue, Papers on city planning in Japan



## 1.26 Tasks and required data/information

Table 0.2 shows the necessary task to be undertaken and related information or data needed in second and third year (basic survey/study for selection of the pilot site, and detailed survey/study for pilot project implementation in the prioritized coastal zone).

Table 0.2: Tasks to be Undertaken for Updating of Information/Database

	<b>Task Item</b>	<b>Type of data</b>	<b>Key Stakeholders</b>
1	Maintenance of the latest topographic map	Topographic data (it could also be outsource to the private company) • DEM (at least 10cm resolution)	MHL
2	Maintenance of the geospatial information of infrastructure	Building data • Shape file of the building (at least for the coastal zone: 1km for the HMW) with GPS coordinate • Other infrastructure data (roads)	MPI(RDA), MHL, Local Authority
3	Survey of the development trends at prioritized coastal area	Type of buildings (use, story, etc.) data • This information shall be integrated in the shape file of the building data mentioned above	MPI, MHL, Local Authority
4	Survey of the High Water Mark	HWM data • Official High Water Mark along the coastal area of Mauritius.	MHL
5	Socio-economic projection	Projection data • Population (by VCA) • Development Index (by VCA) • Others (Development trend, employment, earnings, poverty and others.)	Central Statistics Office
6	Monitoring <sup>23</sup>	Items below shall be continuously monitored; • Erosion rate at each coastal area (topography survey by auto-level, staff, tape measure, GPS and others.) • Wave (pressure, current, temperature and others by wave/current measurement device) • Surge	MOESDDBM (ICZM), MOI
7	Accumulation of the disaster record	Disaster information mentioned below shall be accumulated as database; • Flooding • Cyclone • Storm surge • Torrential rain	NDRRMC, MOESDDBM (PPC), Mauritius Police Fire Services
8	Maintenance/Revision of the Guideline	The maintenance/revision of the guideline shall be undertaken by CCD utilizing the latest information (or data) available in Mauritius.	MOESDDBM (CCD)
9	Feedback from the communities by field study	Attitude, consciousness and awareness of the residents in the target area.	MOESDDBM (CCD)/ Local Authority

<sup>23</sup>The detailed information of the monitoring: Technical Guideline in the final report of “The project for capacity development on coastal protection and rehabilitation in the republic of Mauritius”, 2015

Figure 0.3 shows an output which was obtained by JICA’s project<sup>24</sup> in 2015 as an example of the detailed survey/study in the action plan. In the second or third year of the action plan, this kind of survey/study will be undertaken by stakeholders as identified in Table 4.2 .

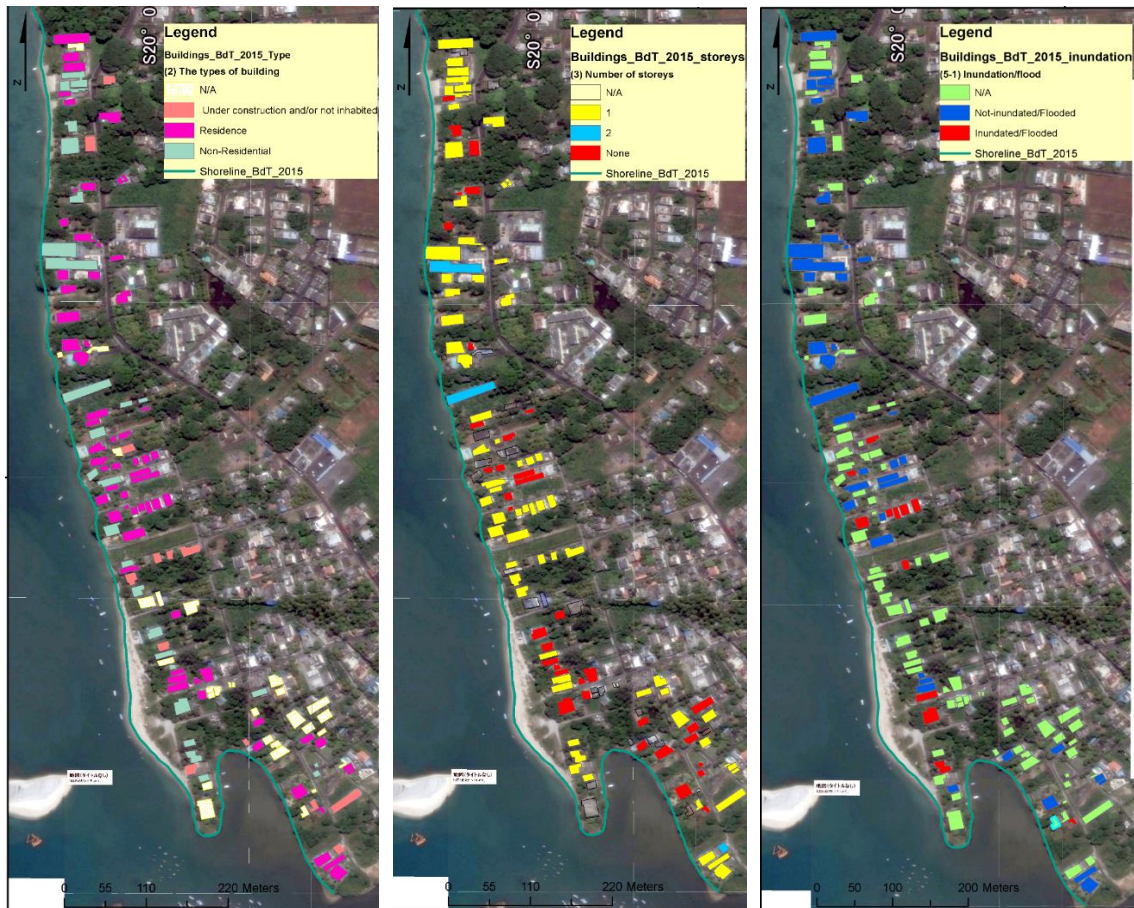


Figure 0.3: An example of the detailed survey (building attribute and disaster record)

<sup>24</sup> The Project for Capacity Development on Climate Change Measure in The Republic of Mauritius (2014-2016)

In the fourth year (Participatory guideline establishment with stakeholders), the stakeholders discuss/examine the specific points of the coastal setback such as contents of standard/restriction, designation of the setback target area, setback distance, management of the regulation and others. For the discussion/examination, the Decision Support System (DSS)<sup>25</sup> will be required.

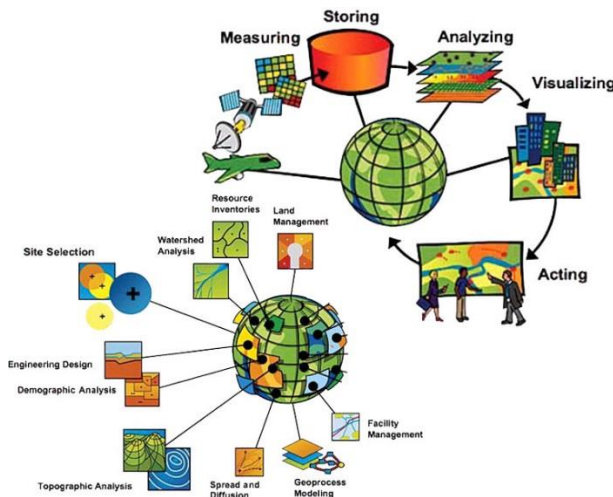


Figure 0.4: Example of Conceptual Image of Decision Support System (DSS)<sup>26</sup>

<sup>25</sup> A decision support system (DSS) is a computer-based information system that supports business or organizational decision-making activities. DSSs serve the management, operations, and planning levels of an organization (usually mid and higher management) and help people make decisions about problems that may be rapidly changing and not easily specified in advance—i.e. Unstructured and Semi-Structured decision problems. Decision support systems can be either fully computerized, human-powered or a combination of both. While academics have perceived DSS as a tool to support decision making process, DSS users see DSS as a tool to facilitate organizational processes. (Keen, Peter; (1980), "Decision support systems: a research perspective. "Cambridge, Mass. : Center for Information Systems Research, Alfred P. Sloan School of Management)

Examples of the DSS (application to the disaster risk management in Japan):

Yoshimizu GONAI et al. (2006); Development of a Support System for Community-based Disaster Mitigation Planning Integrated with a Fire Spread Simulation Model using CA, Innovations in Design and Decision Support Systems in Architecture and Urban Planning, Springer Publishers

Yoshimizu GONAI et al. (2005); Development of a WebGIS Supporting Community-based Planning for Disaster Mitigation Integrated with a Fire Spread Simulation Model using CA, Proceeding of Ninth International Conference on Computers in Urban Planning and Urban Management

<sup>26</sup> ESRI(2007), The Geographic Approach

## 1.27 To promote climate change countermeasure in the relevant policies

In the Planning Policy Guideline (PPG -Design sheet of residential coastal development / resort hotel development), there is a description regarding the setback shown as below;

Buildings and structures should be located as far back as practicable from the shoreline. The setting of structures back from the shoreline offers various advantages:

- Efficient connection to hinterland service systems.
- Reducing wind, salt and sand impact on structures.
- Reducing impact on unstable soils.
- Reducing interference with the flow of littoral sediments.
- Optimizing pedestrian accessibility.
- Minimizing overshadowing.

Not only the above, but also the following function can be expected;

- The risk of inundation, flood, storm surge and others can be reduced by avoiding the new building/development in the area.
- The countermeasure works (physical measure) is not required
- Conservation of the biotope.
- Securement of the public access and recreation space
- Conservation /creation of the integrated landscape between sea and land.

Mauritius has had a continuous control of the development in the coastal area by the PPG. 15 m setback designated by MHL, it was used until 2005, and then it was revised to 30m from HWM (High Water Mark) in 2004<sup>27</sup>.

According to the examination result in the previous chapter, it seems that the effectiveness of setback regulation depends on the area. And the effects of climate change are not fully considered in the current setback policy. Although the setback has been introduced in Mauritius, the future condition is hard to be predicted as climate change issues vary from time to time. Therefore, it is recommended to review the relevant policies and laws based on the achievements such as existing studies, projects, the above action plan and others.

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<sup>27</sup> Design sheet of residential coastal development / resort hotel development in PPG, MHL, 2004

In addition, 81m from the HWM is state-owned land (except for some area) as defined by the Pas Géométriques Act.

## Annexes

## 1. The Intergovernmental Panel on Climate Change (IPCC)

The climate change issues are mostly discussed in the framework of mitigation and adaptation measures in worldwide. The Intergovernmental Panel on Climate Change (IPCC) is the world body for assessing the science related to climate change. The IPCC was set up in 1988 by the World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP), endorsed by the United Nations General Assembly, to provide policymakers with regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation.

In the Fifth Assessment Report (AR5) Working Group II (WGII) of IPCC published the Summary for Policymaker states the core concept as following figure. Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability

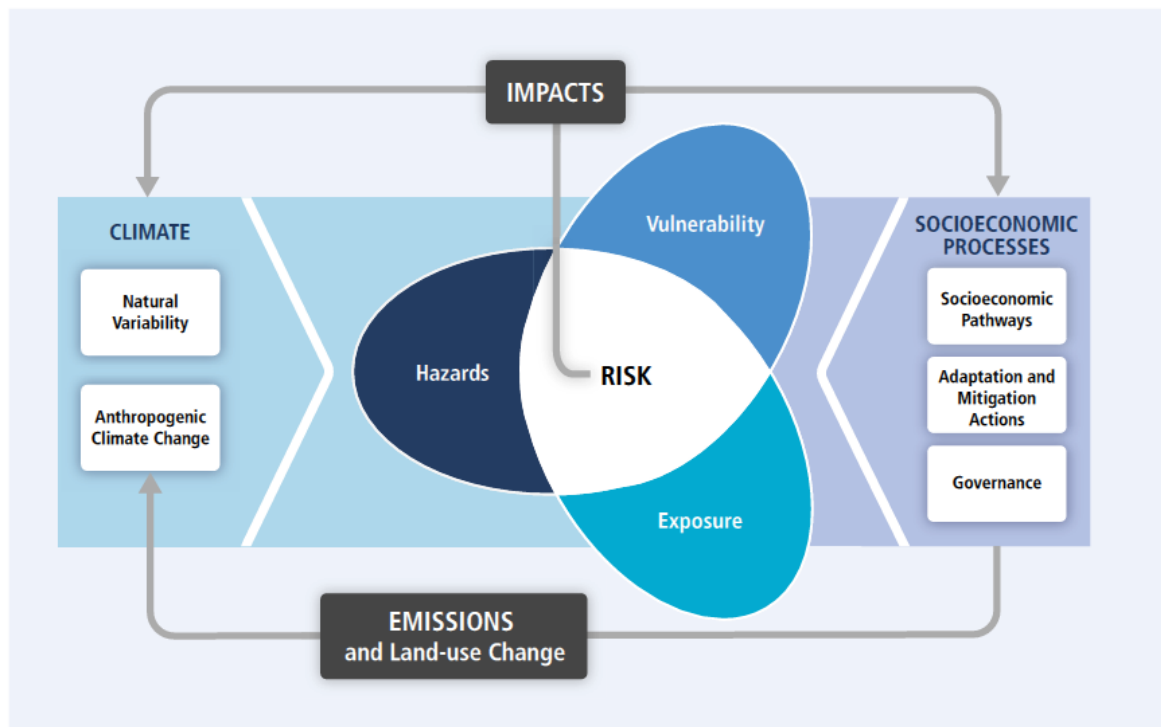


Figure 1.1 Illustration of the Core Concepts of the WGII AR5.



The climate change risks of Mauritius (SIDS) are summarized in the WGII AR5 as follows;

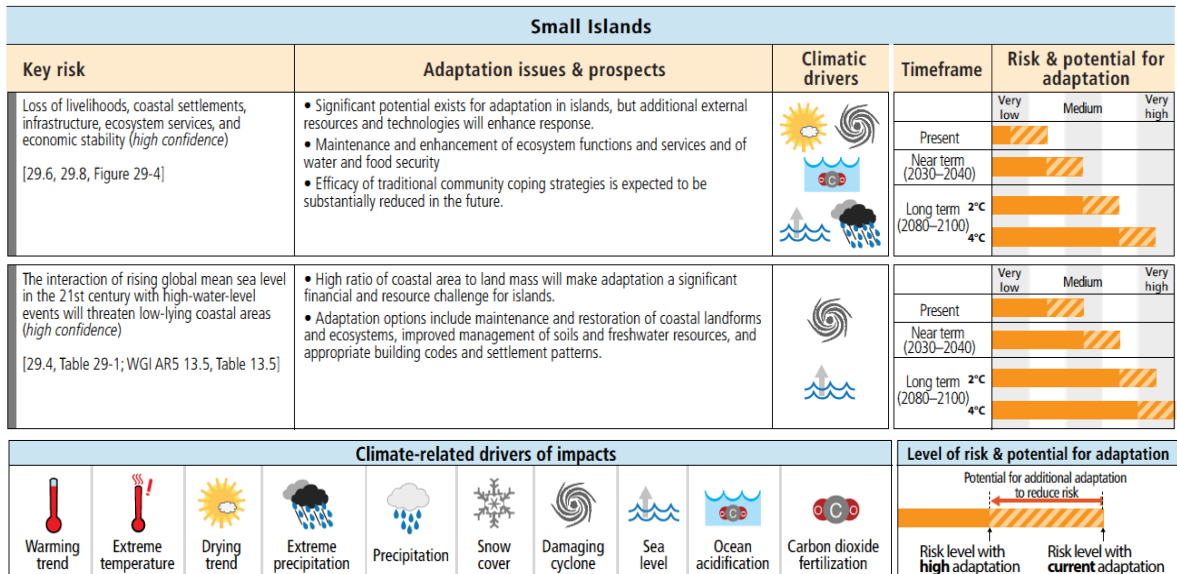


Figure 1.2 Climate-related Drivers of Impact in SIDS

Major risks by the climate change will be such as drying trend, extreme precipitation, damaging cyclones, carbon dioxide fertilization and sea level rise. These risks have big risks to the Mauritius.

However, each of these expected risks shall be studied and monitored with the available data. As the coastal studies are relatively advanced field of area and the data is also available for assessment, This Guideline will focus into coastal setbacks issue.

## 2. Risks by Sea Level Rise (after WGII AR5 (Section 5))

Coastal systems and low-lying areas, also referred to as coasts in this assessment, include all areas near mean sea level. Generally, there is no single definition for the coast and the coastal zone/area, where the latter emphasizes the area or extent of the coastal ecosystems.

In relation to exposure to potential sea level rise, the low-elevation coastal zone (LECZ) has been used in recent years with reference to specific area and population up to 10 m elevation (Vafeidis, et al., 2011). Coastal systems are conceptualized to consist of both natural and human systems.

The natural systems include distinct coastal features and ecosystems such as rocky coasts, beaches, barriers and dunes, estuaries and lagoons, deltas, river mouths, wetlands, and coral reefs. These elements help define the seaward and landward boundaries of the coast. In spite of providing a wide variety of regulating provisioning, supporting, and cultural services (MEA, 2005), they have been altered and heavily influenced by human activities, with climate change constituting only one among many pressures these systems are facing.

The human systems include the built environment (e.g., settlements, water, drainage, as well as transportation infrastructure and networks), human activities (e.g., tourism, aquaculture, fisheries), as well as formal and informal institutions that organize human activities (e.g., policies, laws, customs, norms, and culture). The human and natural systems form a tightly coupled socio-ecological system (Berkes and Folke, 1998; Hopkins et al., 2012).

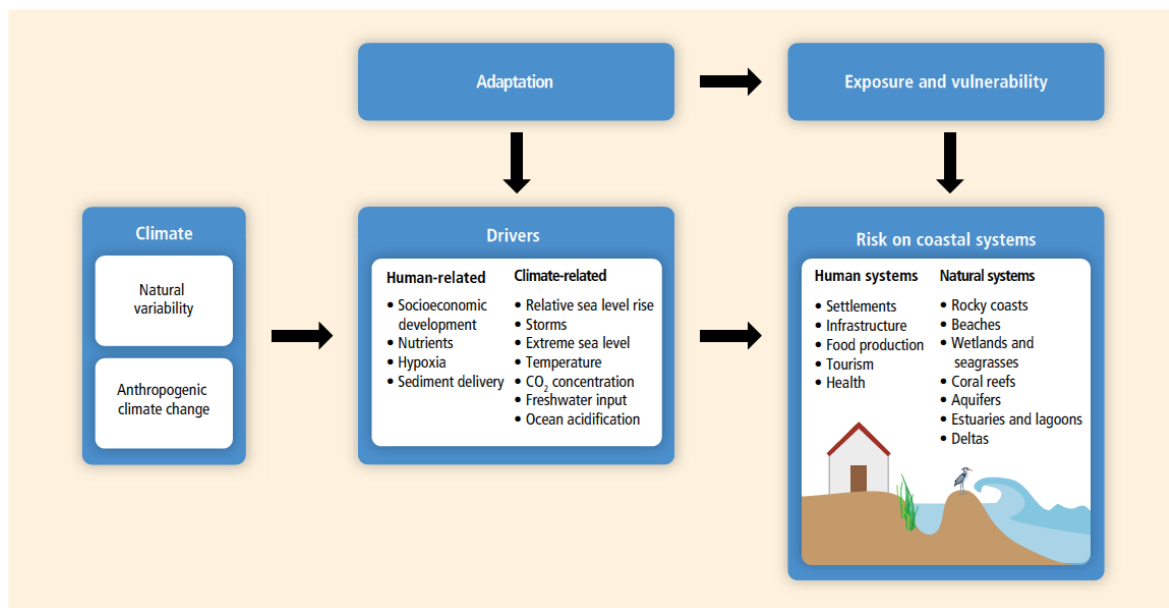


Figure 2.1 Climate, Drives and Risks on Coastal System

It is very likely that global mean sea level rose at a mean rate of 1.7[1.5 to 1.9] mm yr<sup>-1</sup> between 1900 and 2010 and at a rate 3.2 [2.8 to 3.6] mm yr<sup>-1</sup> from 1993 to 2010 (WGI AR5). Ocean thermal expansion and melting of glaciers have been the largest contributors, accounting for more than 80% of the GMSLR over the latter period (WGI AR5). Future rates of GMSLR during the 21st century are projected to exceed the observed rate for the period 1971–2010 of 2.0 [1.7 to 2.3] mm yr<sup>-1</sup> for all RCP scenarios (WGI AR5). Table summarizes the likely ranges of 21<sup>st</sup> century GMSLR as established by the Working Group I contribution to this Assessment Report.

From a coastal risk management perspective (Nicholls et al., 2013) assessments of impacts, vulnerabilities, and adaptation have been using GMSLR scenarios above the ranges put forward by WGI reports of AR4(Meehl et al., 2007) and AR5 (WGI AR5). The ranges estimated by WGI of AR4 and AR5 include only those components of GMSLR that can be quantified using process-based models (i.e., models derived from the laws of physics; WGI AR5). The ranges given in AR4 thus explicitly excluded contributions to GMSLR resulting from changes in ice flows from the ice sheets of Greenland and Antarctica because at that time process-based models were not able to assess this with sufficient confidence (Meehl et al., 2007). Since then, understanding has increased and the likely range of GMSLR given in AR5 now includes ice sheet flow contributions.

Likely, however, means that there is still a 0 to 33% probability of GMSLR beyond this range, and coastal risk management needs to consider this. WGI does not assign probabilities to GMSLR beyond the likely range, because this cannot be done with the available process-based models. WGI, however, assigns medium confidence that 21st century GMSLR does not exceed the likely range by several tenths of a meter (WGI AR5). When using other approaches such as semi-empirical models, evidence from past climates and physical constraints on ice-sheet dynamics GMSLR upper bounds of up to 2.4m by 2100 have been estimated, but there is low agreement on these higher estimates and no consensus on a 21<sup>st</sup> century upper bound (WGI AR5). Coastal risk management is thus left to choose an upper bound of GMSLR to consider based on which level of risk is judged to be acceptable in the specific case. The Dutch Delta Programme, for example, considered a 21<sup>st</sup> century GMSLR of 1.3m as the upper bound.

Table 2.1 Mean Sea Level Rise by Emission Scenario

Emission scenario	Representative Concentration Pathway (RCP)	2100 CO <sub>2</sub> concentration (ppm)	Mean sea level rise (m)		Emission scenario	Mean sea level rise (m)		
			2046–2065	2100		2200	2300	2500
Low	2.6	421	0.24 [0.17–0.32]	0.44 [0.28–0.61]	Low	0.35–0.72	0.41–0.85	0.50–1.02
Medium low	4.5	538	0.26 [0.19–0.33]	0.53 [0.36–0.71]	Medium	0.26–1.09	0.27–1.51	0.18–2.32
Medium high	6.0	670	0.25 [0.18–0.32]	0.55 [0.38–0.73]	High	0.58–2.03	0.92–3.59	1.51–6.63
High	8.5	936	0.29 [0.22–0.38]	0.74 [0.52–0.98]				

### 3. Socio-economic Implications

The table below shows the sectors on which climate change threats such as changes in precipitation pattern, temperature rise, sea level rise and extreme weather events may have an impact on the socio-economic patterns in Mauritius.

Table 3.1: Socio-economic Implications

Sector	Description
Water Resources	<ul style="list-style-type: none"> <li>The average of rainfall decrease per decade is approximately 57 mm and the total decrease in the last 10 years is 8% compared to the 1950s (MMS)</li> </ul>
Agriculture	<ul style="list-style-type: none"> <li>48 % of land in Mauritius is used as an agricultural land</li> <li>68% of water resources are used in the agricultural sector.</li> <li>15.6% of total exports are contributed by agricultural sector</li> <li>The production of sugar cane was increased by 20 per cent between 1999 and 2009 (FAO, 2013, pp. 2-3)</li> </ul>
Tourism	<ul style="list-style-type: none"> <li>Economic revenue from tourism sector in 2013 was 45 billion MUR which was about 8.2% of GDP (BoM)</li> </ul>
Infrastructure	<ul style="list-style-type: none"> <li>For example, heavy rainfall which recorded 152.6 mm in Port Louis on the 30<sup>th</sup> of March 2013 caused flash flood with 11 people's death and infrastructure damages</li> </ul>
Health	<ul style="list-style-type: none"> <li>Average temperature has risen by 0.74 to 1.2 degrees compared to the long term mean between 1961 and 1990 (MMS).</li> <li>Dengue fever is one of the major health concerns in Mauritius</li> </ul>
Livelihood	<ul style="list-style-type: none"> <li>Sea level rise could lead to coastal inundation</li> <li>DRR identified coastal inundation areas in Mauritius, some areas are highly vulnerable to coastal inundation</li> </ul>

## 4. Desk Study - Gaps & Needs Analysis

A Desk Study - Gaps & Needs Analysis was conducted to understand the current existing policies/acts/regulations/guidelines that consider climate change.

The desk study considered the key areas of concern in Mauritius related to the coastal zone; environmental conservation, coastal infrastructure and coastal zone development. Environmental conservation related to environmental protection, climate change adaptation, and other environmental considerations. Coastal infrastructure related to road development, and coastal zone management related to planning guidelines, land use guidelines and building guidelines.

A climate change adaptation guideline on coastal zone management is a guideline where environmental conservation, coastal infrastructure and coastal zone management are all taken into consideration - and one that contains adaptation measures to decrease human and natural vulnerabilities against the impacts of climate change.

The existing documents for study in the above areas is the Tourism Development Strategy and Action Plan, Tourism Sector Strategy Plan 2009-2015, Hotel Development Strategy, Road Development Act, The Environment Protection Act 2002, Integrated Coastal Zone Management Framework (ICZM), EIA Guidelines for coastal construction, Planning Policy Guidelines (PPG), Building and Land Use Permit (BLP), and the Pas Geometriques Act. Details are provided in table below

Table 4.1 Documents Consulted for Desk Review

Policy / Regulation / Act / Guideline	Year of Enactment	Relevant Agency	Description	Provisions Relevant to Adaptation Measures	Possible Gaps	Possible Needs
Hotel Development Strategy	June 2009	Ministry of Tourism and External Communications	Strategy to ensure the sustainable development of the hotel sector	Setback, building height and plot coverage to be considered	Coastal guidelines under the strategy aims at protecting the visual impacts through building design by adhering to the PPG	The negative impacts of hotel development along the coast should be highlighted, especially on beach erosion issues
The Environment Protection Act 2002	2002	Ministry of Environment, Sustainable Development, Disaster and Beach Management	<ul style="list-style-type: none"> <li>- To provide for the legal framework and the mechanism to protect the natural environment</li> <li>- To plan for environmental management</li> <li>- To coordinate the inter-relations of environmental issues</li> <li>- To ensure the proper implementation of governmental policies and enforcement provisions</li> </ul>	Part VII - Coastal and Maritime Zone Management	Relevant regulations/policies/guidelines are not indicated in the Act in order to ensure # <b>3. Protection of the zone</b>	Further details to be identified on # <b>3. Protection of the zone</b> (1) a. the management, protection and enhancement of the environment in the zone (coastal zone)

Integrated Coastal Zone Management Framework (ICZM)	2009	Ministry of Environment, Sustainable Development, Disaster and Beach Management	To maintain a high quality coastal environment and conserve coastal and marine biodiversity	<ul style="list-style-type: none"> <li>- Provides principles and guidelines on sustainable development, population concentration in the coastal zone, investment and human resource interactions in the environment</li> <li>- Provides a proper management plan for the coastal zone</li> </ul>	N/A	N/A
Guideline for construction of marinas (EIA report requirement)	December 2013	Ministry of Environment, Sustainable Development, Disaster and Beach Management	A guideline to identify issues related to building marinas	<ul style="list-style-type: none"> <li>- A detailed investigation of the site to be conducted</li> <li>- A vulnerability of the site to natural hazard, sea surges or climate change impacts like sea level rise, inundation or flooding</li> <li>- Details justifying how the development will be climate proof</li> </ul>	Guideline mentions the need for proposed adaptation and mitigation measures, but gives no details as to the methodology	Details to be provided on how to conduct the investigation related to climate change issues
Guideline for proposed coastal hotel projects (EIA report requirement)	N/A	Ministry of Environment, Sustainable Development, Disaster and Beach Management	A guideline to ensure that all environmental parameters have been addressed and taken into account in the project design	<ul style="list-style-type: none"> <li>- Setback shall be at least 15 m from the high water mark depending on the specificity of the site</li> <li>- No development shall be allowed on sensitive coastal areas, including mangroves, wetlands and sand dunes</li> </ul>	Guideline does not explain the setback rule in detail	Setback should have details on each type of site specificity

<p>Planning Policy Guidelines (PPG)</p>	<p>2005</p>	<p>Ministry of Housing and Lands</p>	<ul style="list-style-type: none"> <li>- A national planning instrument</li> <li>- To create a set of performance criteria and design standards for key activities, namely, residential, commercial, industrial, hotels and integrated resorts</li> </ul>	<ul style="list-style-type: none"> <li>- Residential Coastal Development - setback, coastal road wall height, no paved road or car park nearer than 30m high water mark, existing mature trees to be retained, setback from natural areas (wetlands), ESAs need to be protected</li> <li>- Setback from the high water mark should be determined on a site by site basis but should normally be a minimum of 30 meters</li> <li>- Setback space to be well landscaped with appropriate coastal vegetation to limit coastal erosion</li> <li>- Removal of coastal features, such as, rocky outcrops, which help maintain the stability of the beach system breaking waves and currents, should be avoided</li> </ul>	<p>No technical details on specific guidelines to setback</p>	<p>A technically backed reason for setback in specific cases, such as, ESAs, natural areas such as, wetlands and beaches and the reason for their benefit</p>
<p>Building and Land Use Permit (BLP)</p>	<p>2005</p>	<p>Ministry of Local Government</p>	<p>A formal request for permission to carry out a proposed development/building construction</p>	<p>Setback of 30m from high water mark on coastal frontage and 6m from a classified road, indicated for coastal development</p>	<p>No technical details/background on specific guidelines to setback in specific areas</p>	<p>A technically backed reason for setback in specific cases, such as, ESAs, natural areas such as, wetlands and beaches and the reason for their benefit</p>



Pas Geometriques Act of 1982	1982	Ministry of Housing and Lands	Ownership and controlling mechanism for most coastline development	Reserved land that extends from the high water mark to a distance of no less than 81 m and 21 cm landward and forms part of the domaine public and shall be inalienable and imprescriptible	Limited enforcement	Management of coastal zone to be reviewed along with other institutions and other policies
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The direct description related with climate change could not be shown in the following documents which were also reviewed in this desk study. But there is possibility some kind of relation with climate change in the following documents, in case of reviewing from view point of the broad/expanded sense.

- 1) Tourism Development Strategy Action Plan
- 2) Tourism Sector Strategy Plan 2009-2015
- 3) Road Development Act
- 4) The Fisheries and Marine Resources Act 2007
- 5) Beach Authority Act 2002
- 6) Building Act
- 7) Town & Country Planning Act 195
- 8) Local Government Act 2003
- 9) Planning & Development Act 2004
- 10) Maritime Zones Act 2005
- 11) Tourism Act 2006

The Gap Analysis will consider the current/existing situation in comparison to the future desired state, which provides a safer option to resilience against climate change impacts along the coast.

The Needs Analysis is the process of identifying and evaluating needs in a community or other defined population of people. The identification of needs is a process of describing “problems” of a target population and possible solutions to these problems.

Table below outlines the gaps and needs of the existing documents which have been reviewed.

A climate change adaptation guideline will bridge the gap between the future desired situation (how things should be to minimize impacts on people and infrastructure) and the current situation (how things are and what impacts they are having on the coastal zone).

The needs column will be analyzed to ensure that value is added to the existing documents through a new Coastal Adaptation Guideline, so as to consider in detail the coastal adaptation options related to climate change.

## 5. Best Practices on Climate Change Adaptation

SIDS face challenges, such as, low availability of natural resources, a rapidly growing population, remoteness, susceptibility to natural disasters, and excessive dependence on international trade.

Many SIDS can become uninhabitable in the future due to changes in precipitation (causing drought which affects drinking water directly and food security through agriculture), sea surface temperatures (causing coral bleaching which affects fisheries and reduces storm surge protection) and extreme events (which impact infrastructure, agriculture and cause salt water intrusion into the freshwater lens).

Coastal erosion is a major problem in small island states. It is a natural process which redistributes sediments however it can be accelerated by both natural and anthropogenic causes. Natural causes include hurricanes, cyclones and storms. Anthropogenic activities include unwise building practices on the coast and activities leading to the destruction of the coral reefs.

Best practices on climate change coastal adaptation are wide and varied. Many studies have been conducted around this topic which aims to provide solutions to the ever increasing risk that climate change poses to coastal regions.

According to the IPCC, adaptation strategies are classified among the *protect*, *retreat* and *accommodate* categories. There are many different technologies that describe these categories, some of which have been listed in the table below.

Table 5.1 Application and Technology for the Adaptation Strategies

Application	Technology
<b>Protect</b>	
Hard structural options	seawalls, dikes, detached breakwaters
Soft structural options	beach nourishment, dune restoration, wetland restoration
Indigenous options	stone walls, afforestation
<b>Retreat</b>	
Increasing or establishing setback zones	limited technology required
Relocation	various technologies
<b>Accommodate</b>	
Modification of building styles and codes	various technologies
Emergency planning	early-warning systems, evacuation systems

Source: <http://www.ipcc.ch/ipccreports/sres/tectran/index.php?idp=299>

Integrated coastal zone management and ecosystem-based adaptation are proven frameworks that can facilitate the implementation of appropriate accommodation strategies. These strategies include measures such as coastal forest rehabilitation, beach dune restoration, and design structures that take the dynamic changes in the coastal zone into consideration. In many cases, these accommodation strategies - such as constructing homes on stilts rather than surrounding them with barriers - may provide a more cost-effective and resilient approach for adaptation.

There is no one solution to climate change coastal adaptation, but rather a range of technologies/options are available that can allow SIDS to investigate and understand the options available. This would allow SIDS to be able to evaluate whether those options will work in their context.

Several documents were studied to extract information for best practices on climate change adaptation. Following are the documents reviewed:

Table 5.2: Key Points from the Reviewed Best Practices

Country	Title	Description	Key Points
Canada	Climate Change Impacts and Adaptation, A Canadian Perspective, 2004	Developing an effective strategy for adaptation requires understanding of vulnerability to climate change	<p>Adaptation strategies under the protect, accommodate and retreat response options to be considered</p> <p>Adaptation strategies are most effective when incorporated with other policies such as disaster mitigation and land-use plans</p> <ul style="list-style-type: none"> <li>-Increase in soft protection</li> <li>-Reliance on technology</li> <li>-Awareness raising</li> </ul>
USA	The State of Adaptation in the United States An Overview, EcoAdapt, USA, 2013	Adaptation can be thought of as a cycle of activities that ultimately reduces vulnerability to climate change. This process starts with identifying the impacts of climate change to determine the types of problems climate change might pose	<ul style="list-style-type: none"> <li>- Create an Adaptation Help Desk</li> <li>- Support jurisdictions that want to take action</li> <li>- Share the lessons of what is being done</li> </ul> <ul style="list-style-type: none"> <li>- Build capacity</li> <li>- Implementation (actual adaptation action)</li> <li>- Monitoring and evaluation</li> </ul> <p>The Adaptation Process is not a one-way path to a solution, rather it is an iterative, perpetual endeavor to improve our understanding and adjust our approaches to achieve better outcomes as the climate changes and we learn more</p> <p>Adaptation success more likely by building solutions across sectors. Need to create more multi-stakeholder and multi-sectoral processes and approaches</p>

USA	Adapting to Coastal Climate Change, A Guidebook for Development Planners, 2009	An approach for assessing vulnerability to climate change and climate variability, developing and implementing adaptation options, and integrating options into programs, development plans and projects at the national and local levels	<ul style="list-style-type: none"> <li>- Assess vulnerability - how climate change will impact coastal communities</li> <li>- Select course of action - to address the full range of coastal climate change hazards</li> <li>- Mainstream coastal adaptation into coastal policies at all levels</li> <li>- Implement Adaptation</li> <li>- Evaluate for adaptive management - coastal adaptation is an iterative process</li> </ul>
Asia	Technologies to Support Climate Change Adaptation, Asian Development Bank	A key component of adaptation is technology. The report identifies a number of existing and emerging technologies that can help Asia adapt to climate change	Coastal sector-specific technologies - structural barriers, geosynthetics, artificial wetlands and reefs, beach nourishment and dune construction, and elevation, land reclamation, flood resilience and flood proofing.
Maldives	Economic Costs and Benefits of Climate Change Impacts and Adaptation to the Maldives Tourism Industry. Increasing Climate Change Resilience of Maldives through Adaptation in the Tourism Sector, 2015	This study assessed the benefits and costs of adaptations to climate change using two approaches: multi-criteria analysis and a benefit-cost analysis. A desktop review of existing data and literature, field survey/mission to evaluate climate adaptation options and an email survey was conducted to collect data	<ul style="list-style-type: none"> <li>- Promote soft adaptation options</li> <li>- Mainstream adaptation in planning and decision-making</li> <li>- Promote dual-benefit solutions</li> </ul> <p>Land-use setbacks as an adaptation option</p>
SIDS	Coastal Zones and Climate Change, Stimson Pragmatic Steps for Global Security, 2010	This document assessed some innovative adaptation and sustainable technologies in SIDS, such as, Implementing Protection/Accommodation Adaptation Strategies in Seychelles, Retreat and Relocation Adaptation Strategies in the Maldives, and SIDS Mitigating Climate Change: Developing Biofuels in Vanuatu	<ul style="list-style-type: none"> <li>- Appropriate national frameworks and institutions to support technology development and transfer are imperative</li> <li>- Innovative, sustainable and integrated approaches to provide resilience to societies and ecosystems must also be considered and not only hard engineering solutions</li> <li>- Appropriate technology transfer frameworks to ensure reduction of climate change</li> </ul>

Other Examples;

**Barbados**<sup>28</sup>: A national statute establishes a minimum building setback along sandy coasts of 30 m from mean high-water mark; along coastal cliffs the setback is 10 m from the undercut portion of the cliff.

**Aruba and Antigua**<sup>28</sup>: Setback established at 50 m inland from high-water mark

**Sri Lanka**<sup>28</sup>: Setback areas and no-build zones identified in Coastal Zone Management Plan. Minimum setbacks of 60 m from line of mean sea level are regarded as good planning practice.

**Seychelles**: A retreat strategy against climate change risks such as sea level rise, storm surge and flooding. In Seychelles, a 25-meter minimum setback distance requirement (unlegislated) has been imposed on developers as a planning tool as well as an adaptation strategy for the future.

**Hawaii**: Setback distance is 40ft + (buildings life cycles values × annual erosion rate)

A soft engineering approach to beach protection and restoration of dunes. A modified version of a coastal protection method involving wooden logs of diameters not more than 20 centimeters driven into the sand was adopted. The modification entailed introducing a second layer of wooden logs, in the form of a sandwich, the middle of which is lined with geotextile and filled with medium-sized rocks for additional strength. The second layer would act as the ultimate barrier in the case of an extreme wave event and also create a topographic profile to enable the sand to cover the proposed structure. In addition, relatively mature seawater-resilient plants were planted in the area behind the wooden pillars, with the aim of further reinforcing the beach berm from potential wave spillovers.

After one year of monitoring, an assessment was made. The beach protection approach yielded positive results in every possible wave regime at that pilot location during different times of the year. This method has since been promoted nationally at several other locations. However, a key consideration is the need for continuous coastal vegetation replanting to ensure long-term stability of the beach berm.

In conclusion, it was observed that coastal adaptation technologies require a thorough assessment of the coastal dynamics and close consideration of the various uses made of coastal zones.

The range of appropriate options will vary amongst and within countries, and different socio-economic sectors that may prefer other adaptation options. It is important to note that successful adaptation not only involves technological options, but it must also be implemented effectively in an appropriate economic, institutional, legal and socio-cultural context.

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<sup>28</sup> <http://www.ipcc.ch/ipccreports/tar/wg2/301.htm>

## 6. Vulnerability Assessment

### a. Basic Concept, Purpose and Workflow

A wide range of skills, knowledge and experience will be required to work on climate change adaptation measures. It is a difficult task to acquire the skills/knowledge/experience of all the fields for this guideline's user. As a starting point, this guideline attempts to introduce a basic methodology of vulnerability analysis for climate change adaptation focusing on coastal area through an example of a case study.

Based on the above, this chapter introduces a methodology of the vulnerability analysis through a case study of the inundation risk and setback examination in the coastal area.

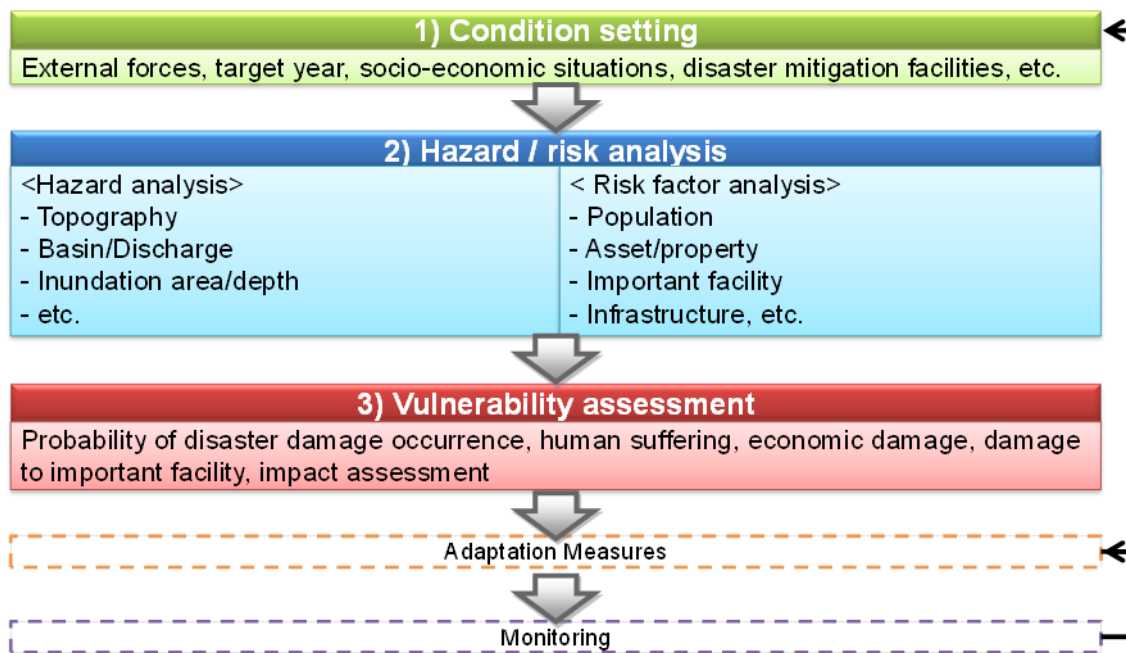


Figure 6.1 Summary of Vulnerability Assessment Workflow<sup>29</sup>

**1) Condition setting:** In order to understand hazards, vulnerabilities, and risks, it is necessary to set appropriate conditions of external forces such as precipitation; the target year for assessment, socio-economic situations, and the development status of disaster mitigation facilities, and then to analyze the hazards, vulnerabilities, and risks. First, external forces are assessed with multiple climate change scenarios exceeding the safety levels of current measures to understand the impacts on various climate change scales. Also, to understand the impact of changes in future projection values, multiple future climate change projection values set under the present study are assessed. Furthermore, to understand the impact of changes at each phase of adaptation measures, the target year for adaptation measures should be assessed, if necessary. In this case, socio-economic conditions should be set as land use, population and property distribution in each target year for the assessment and the condition of disaster mitigation facilities should be set assuming the development status of disaster mitigation facilities based on previous plans, etc.

<sup>29</sup> Modified from Practical Guidelines on Strategic Climate Change Adaptation Planning-Flood Disaster-, Ministry of Land, Infrastructure, Transport and Tourism, Japan



2) Hazard / risk analysis: To analyze the hazard/risk, it is necessary to calculate the economic, human, and core facilities damages, and failure of central functions. In estimating the impacts for these damages and failure of central functions, a model for the process of cyclone, high wave, sea level rise, precipitation and runoff needs to be created for analysis of flood/inundation area and depth. In order to have a better understanding of the inundation areas, it is important to estimate the population in the target area, the height of inhabited buildings, property, core facilities, etc. Using the calculation results, human, economic and core facilities damages; and failure of central functions are estimated. It is money/time consuming to construct and run a model combining various element models with the aim of simulating complex physical phenomena. If a sufficient amount of data is not available for analysis, one option is to use a simple alternative method such as using past flood data.

3) Vulnerability assessment: It is necessary to identify as clearly as possible, the possibility of flooding and what/how could be damaged by inundation and how, before analyzing them. It is very important to use various indices for the analysis, not a single index. It is also important to analyze the effects of inundation; and the area, population and facilities affected by inundation from diverse points of view. Specifically, human, economic, and core facilities damages should be calculated in view of the inundation in the floodplain. Based on the estimated extent of damages to central functions, various damages caused by flooding are usually analyzed. When performing such analyses, it is important to concretely estimate and understand not only direct effects but also indirect effects, such as the effects of inundation damage in the floodplain and the interruption of the movement of people and goods due to inundation on the social and economic activities in and outside the floodplain, and the spreading of epidemics and the occurrence of communicable diseases due to the deterioration of sanitary conditions. It is important to comprehensively understand the vulnerability based on regional characteristics, present situation, and future trends by effectively using these analysis results.

In general, the methods for climate change projection and inundation calculations have been developed based on dynamic and statistical theories. As the calculation results include uncertainties, highly-reproducible analytical methods should be appropriately selected for respective methods, and the reproducibility of phenomena and the accuracy should be confirmed.

It is important to choose a method considering the necessary accuracy in inundation analysis, output reproduced by each method, time/labor, topography and others, and to confirm the reproducibility of past inundation records.

Regarding the level of reproducibility and accuracy of methods, it is important to ensure reliability to understand risks and to consider the countermeasures according to the purpose of analysis, the characteristics of each analysis method and the accuracy of data used.

Uncertainties associated with climate change projection include the following points;

- Uncertainty inherent in the global warming scenarios themselves. This is evident from the fact that a number of cases are assumed in connection with the global warming scenarios.
- Projections made by use of global climate models. This is because there may be differences in projection results among different global climate models.
- Downscaling needed for the reproduction by global climate models. This arises because future projections of the space-time distribution of climate change to be used in actual

analyses vary depending on the downscaling methods used.

- The prediction of future changes in the subject area’s vulnerability (e.g., population, property).

When trying to identify risks, it is necessary to understand the above uncertainties in advance.

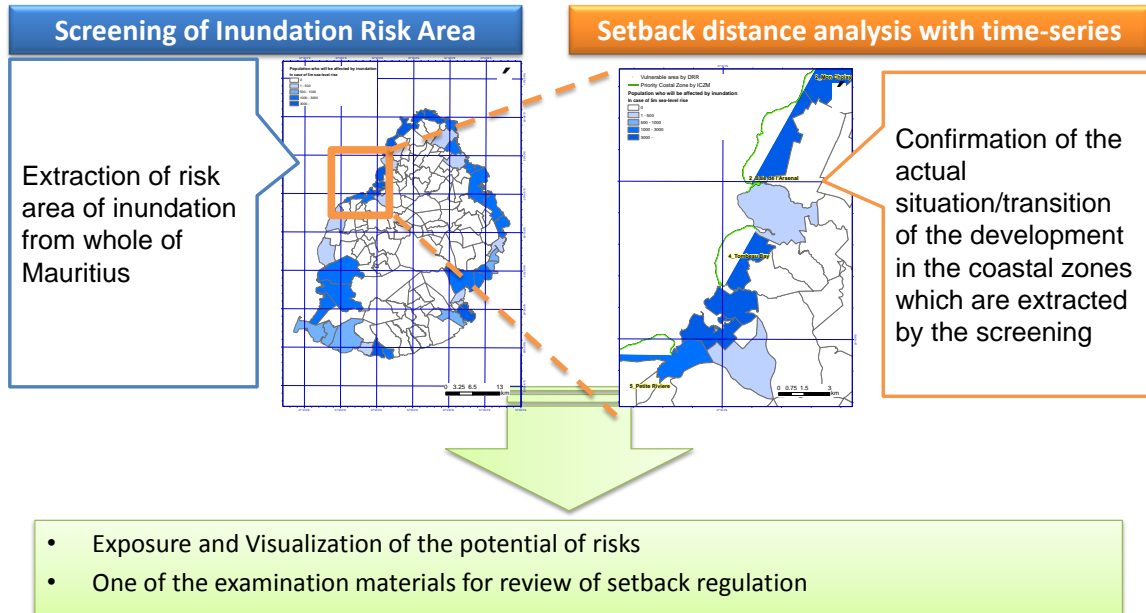


Figure 6.2 Conceptual Image of the Vulnerability Analysis in this Guideline as an Example of Case

Figure 6.2 shows a conceptual image of the vulnerability analysis which is explained in this guideline as an example of case study. The risk areas of inundation are extracted by VCA from the whole island to demarcate the location and distribution. Based on the result, the target area is set to confirm the actual situation/transition of the building development in the coastal zones which are extracted by the screening.

### b. Screening of Inundation Risk Area

The screening analysis is conducted by GIS with the available data in Mauritius. The area which will be affected by coastal inundation (1m sea level rise) is shown in Figure 0.3. Figure 0.4 shows VCA population which will be affected by coastal inundation. The lists of data and analysis steps are included in the annex. The criteria and range for the classification shall be decided depending on the purpose of the output.

The SLR of 1m is a projection for 2065<sup>30</sup> and the analysis to consider SLR for the short term could not be conducted as there is no topographic data (DEM) which has a higher resolution of 1m available in Mauritius. However, the consideration for the short term can be conducted if the higher resolution (at least 10cm) is available in the future.

<sup>30</sup> Fifth Assessment Report (Synthesis Report) by IPCC (Intergovernmental Panel on Climate Change), 2013

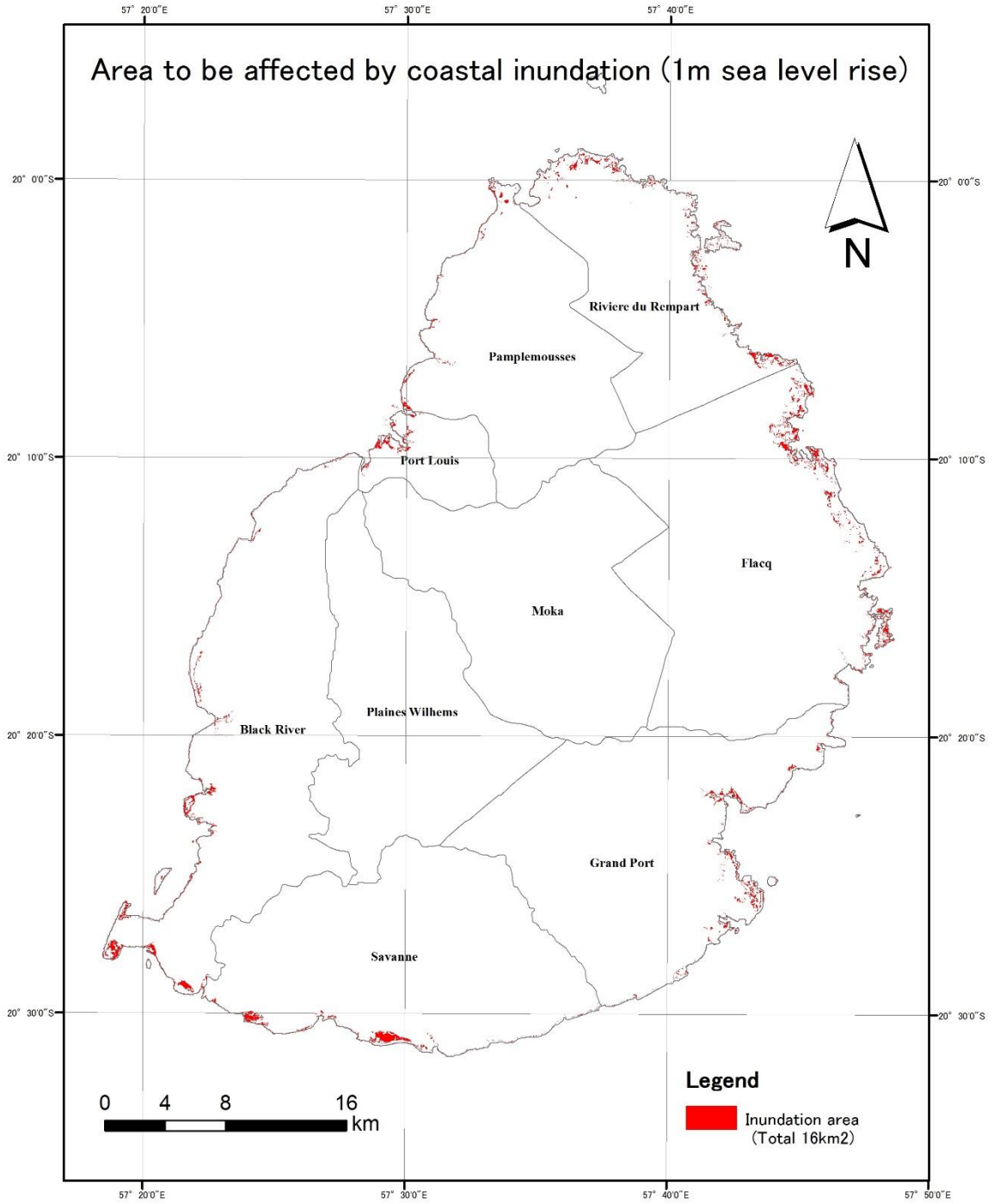


Figure 6.3: Area to be Affected by Coastal Inundation (1m Sea Level Rise)

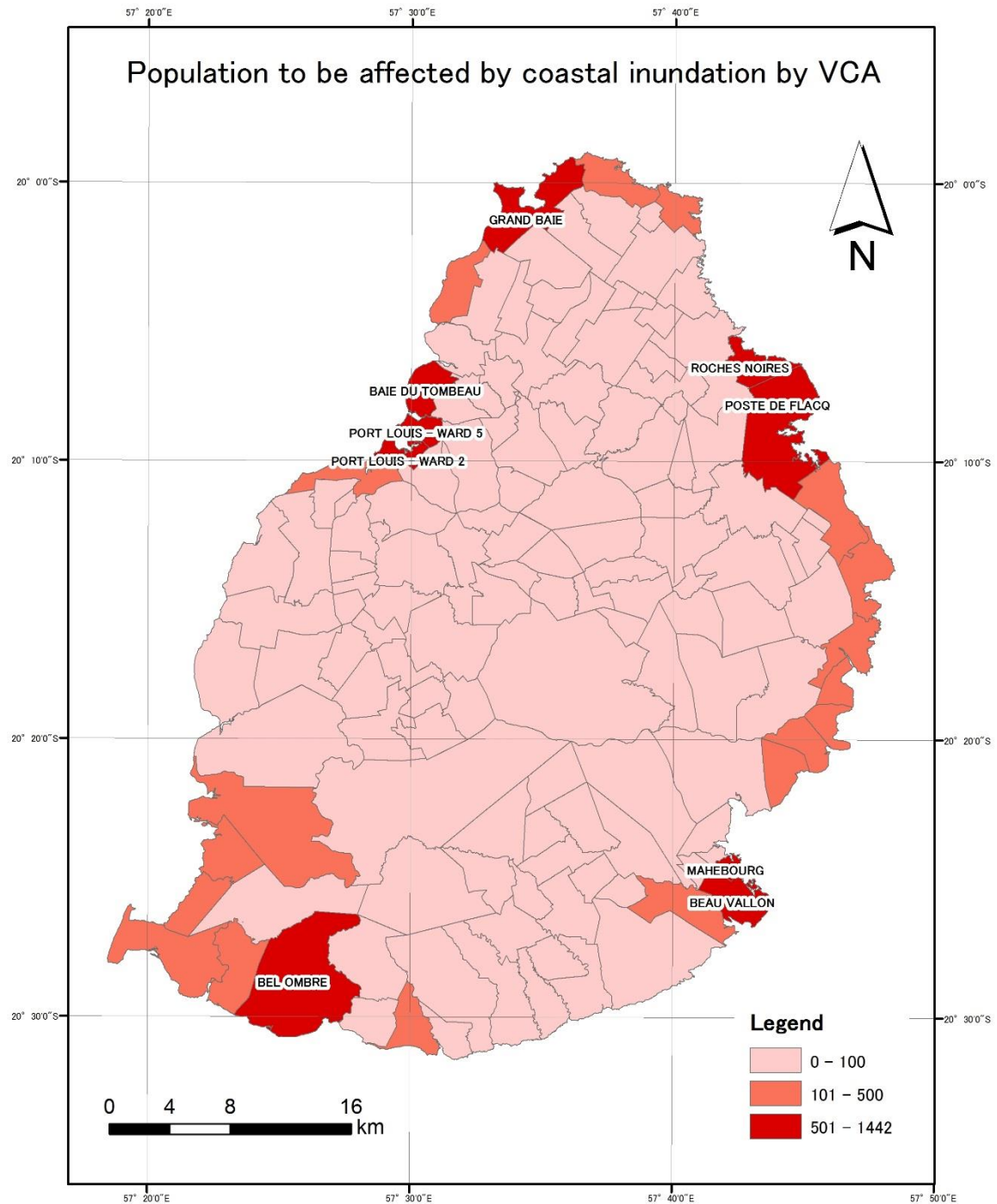


Figure 6.4 Population to be affected by Coastal Inundation by VCA

This result also can be compared or combined with the result of the other findings to have a larger perspective of view. The table below shows the summary of the nine VCA which was classified with the highest population to be affected by coastal inundation (501-1442 peoples) from the figure above. In the selection of the target area for setback distance analysis, the priority coasts which were designated by the ICZM, vulnerable coast mentioned in the Final Report of DRR and coastal conservation plan by JICA project has been added into the table for the consideration.

Table 6.1 Population to be affected by Coastal Inundation in 2065<sup>31</sup>

Assessor Village Council Area	Population to be affected (Actual)	Priority Coast by ICZM	Vulnerable Coast by DRR	Coastal Conservation Plan by JICA
Mahebourg	1442	×	○	×
Baie du Tombeau	1084	○	○	○
Port Louis-Ward 2	880	×	○	×
Roches Noires	760	○	○	×
Beau Vallon	726	○	×	○
Poste de Flacq	718	○	○	○
Grand Baie	672	○	○	○
Bel Ombre	579	○	×	○
Port Louis-Ward 5	542	×	○	×

○: Yes, ×: No

The target area for the setback distance analysis will be selected following the criteria below;

1. Highest population to be affected with coast prioritized by ICZM, DRR and JICA



2. Highest population to be affected with coast prioritized by two of above



3. Highest population to be affected with coast prioritized by one of above



4. Highest population to be affected

After the selection based on the criteria above, the coasts for the setback distance analysis (the setback distance analysis) was prioritized as below.

- 1) Baie du Tombeau
- 2) Poste de Flacq
- 3) Grand Baie
- 4) Roches Noires
- 5) Beau Vallon
- 6) Bel Ombre
- 7) Mahebourg
- 8) Port Louis – Ward 2
- 9) Port Louis – Ward 5

<sup>31</sup> Each assessor used their original methodology, algorithm and data, therefore the prioritization result is different.

## 7. Screening of Inundation Risk Area in Coastal Zone

The analysis of this section carries out to identify the assumed inundation area/population by the climate change on the macro scale (whole island of Mauritius). These areas can be identified using GIS software and the existing data which is available in Mauritius. Figure 7.1 shows the concept for the screening analysis output which is be obtained through Geo-spatial analysis.

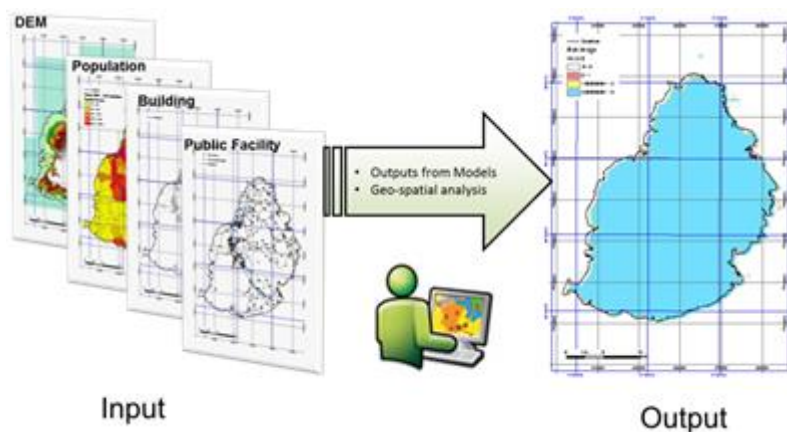


Figure 7.1 Concept of the Output by Geo-spatial Analysis

### a. Data Collection and Compiling

GIS data can be roughly classified into three types which are 1) Basic Data, 2) Natural Condition Data and 3) Social Condition Data.

#### 1) Basic Data

The list of the major basic data available in Mauritius is as shown below.

Table 7.1 List of Major Basic Data

No	Name	Type	Scale/Resolution	Source
1	Digital Elevation Model (DEM) <sup>32</sup>	DEM	XY: 10m x 10m Z: 1m	MHL
2	District Boundary	Polygon	1:50,000	ICZM/MHL
3	Gazetteer	Point	1:50,000	ICZM/MHL
4	Rivers	Polyline	1:50,000	DRR
5	Roads	Polyline	1:50,000	ICZM/MHL
6	Village Council Area (VCA)	Polygon		ICZM

<sup>32</sup> DEM used for the analysis is 1m resolution obtained by MHL (2008). It is not interpolated data; it is row data which is made from aerial photo survey.

2) Natural Condition Data

The list of the major natural condition data available in Mauritius is as shown below.

Table 7.2 List of Major Natural Condition Data

No	Name	Type	Scale/Resolution	Source
1	Coastline	Polyline	1:50,000	ICZM/MHL
2	District Boundary	Polygon	1:50,000	ICZM/MHL
3	Forest Quality	Polygon		
4	Lakes Reservoir	Polygon	1:50,000	ICZM/MHL
5	Mangroves	Polygon		ESA
6	Reefs	Polyline	1:50,000	ICZM/MHL
7	Lagoon	Polygon		ESA

3) Social Condition Data

The list of the major social condition data available in Mauritius is as shown below.

Table 7.3 List of Major Natural Condition Data

No	Name	Type	Scale/Resolution	Source
1	Airport	Polygon	1:50,000	ICZM/MHL
2	Built-up Area	Polygon	1:50,000	ICZM/MHL
3	Census 2011	Polygon		Central Statistical Office
4	Hotels	Point	1:50,000	ICZM/MoT
5	Landfill	Polygon		MHL
6	Medical Facilities	Point	1:50,000	ICZM/MHL
7	Schools	Point		

Figure 7.2 shows the examples of the visualized GIS data available in Mauritius.

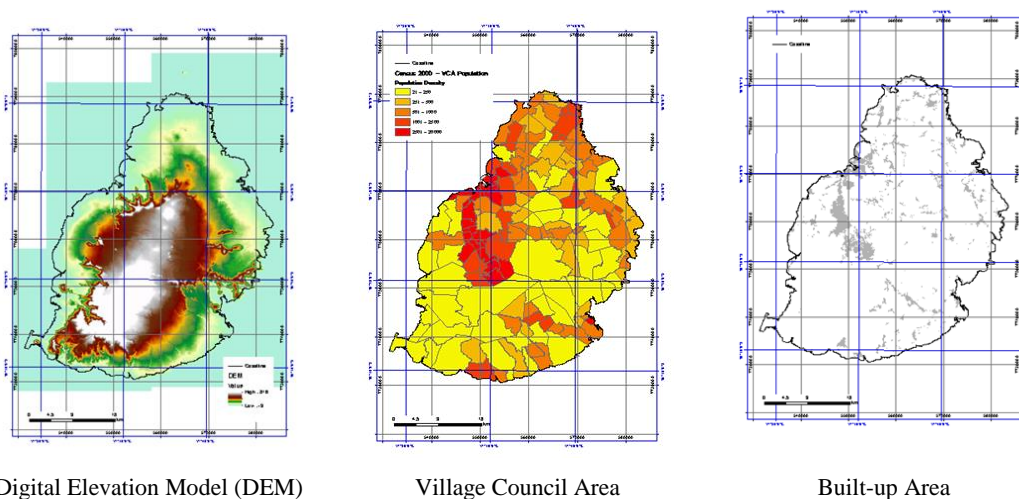


Figure 7.2 Example of Data Available in Mauritius

**b. Condition Setting**

In this guideline, the screening analysis carries out to assess the population to be affected by

coastal inundation due to sea level rise throughout Mauritius in 50 years (2065). An appropriate scenario should be selected, taking into consideration the uncertainty at each step, from a number of warming scenarios based on projected future changes in socio-economic conditions. Under the scenario, precipitation should be determined as a range of values from projection results obtained from a climate change model such as global climate model (GCM) by performing downscaling and analyzing precipitation statistics. It is important that the global warming scenarios are developed properly based on the projected future precipitation patterns though it will change depending on the global efforts to reduce greenhouse gas emissions.

There are various results of global warming scenarios which can be adapted to the macro analysis in Mauritius such as;

- 1) Fifth Assessment Report (Synthesis Report) by IPCC (Intergovernmental Panel on Climate Change)
- 2) Final Report of Disaster Risk Reduction Strategic Framework and Action Plan (DRR) by AAP (African Adaptation Programme)
- 3) Assessing the Costs of Coastal Inundation for Baie du Tombeau, Port Louis, Mauritius by IOC (Indian Ocean Commission)

Table 7.4 Scenario of Sea Level Rise in 2065

	1) IPCC	2) AAP	3) IOC
Sea Level Rise (m)	0.22 to 0.38 <sup>*1</sup>	0.5 <sup>*2</sup>	0.63 <sup>*3</sup>

\*1 Global Mean Sea Level Rise by RCP 8.5 of 2046 to 2065 (Synthesis Report, Pg. 60)

\*2 A1F1, downscaled for Mauritius using MAGICC-SCENGEN v.5.3 (Pg. 90)

\*3 RCP 8.5-high, 24-GCM-ensemble, 75-percentile (Pg.9)

The global warming scenario of 3) IOC (0.63m) will be used for the screening in this guideline because the model has been downscaled and has the highest value among these three results.

### c. Analysis procedure

The output result through this analysis will be the population to be affected by coastal inundation by 2065. Figure below shows the conceptual diagram of algorithm of assumed inundation area / population for the macro analysis. This algorithm can include/consider not only population but also building, hotels, health centers, roads and others, if the data is available.



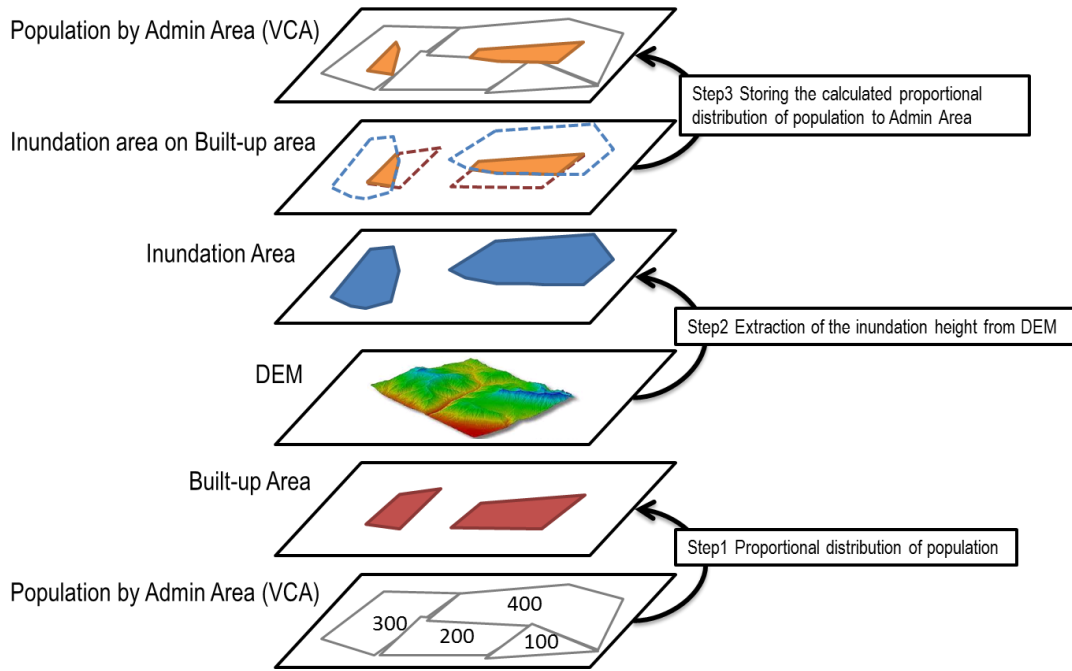


Figure 7.3 Conceptual Diagram of Algorithm of Assumed Inundation Area/Population

Step 1 Proportional distribution of population

The GIS data required for this step is the population by VCA and built-up area. The population data of 2011 was used here as it is the latest digitize data which is available in Mauritius.

In this step, the population is allocated proportionally into the built up area in the VCA. Figure below shows the concept for proportional distribution of population.

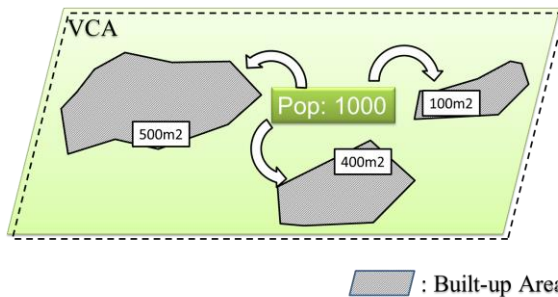


Figure 7.4 Concept of Proportional Distribution of Population

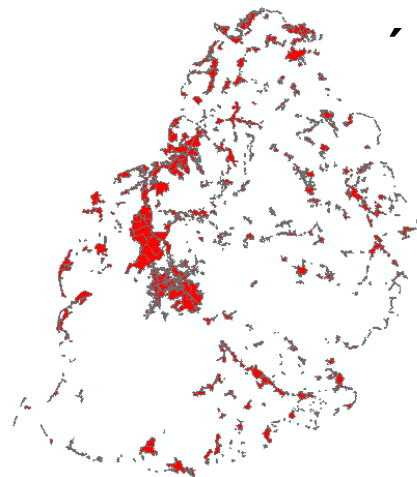


Figure 7.5 Output Result of Step 1

Step 2 Extraction of inundation height from DEM

The GIS data required for this step is DEM data. The DEM of 2008 is used for this analysis as it is the latest DEM data available in Mauritius. In this step, the elevation of 0~1m (inundation height) is extracted from the DEM data. The scenario value for sea level rise was changed from 0.63m to 1m in this extraction process due to the reason mentioned below;

- (1) The resolution for the elevation of DEM data available in Mauritius is 1m. This mean the extract value shall be equal or greater than 1m.
- (2) Due to the reason above, the storm surge was taken into the consideration. The value is obtained from the Final Report of Disaster Risk Reduction Strategic Framework and Action Plan (refer to Table 7.5).

Table 7.5 The Additional Value for Storm Surge<sup>33</sup> (red bracket)

Parameter	RP 25 years	RP 50 years	RP 100 years	Extreme
Significant Wave Height (m)	8.5	9.7	10.8	13.5
Significant Wave Period (s)	9	10	11.5	15
High Tide (m)	0.5			
Sea level rise (m)	0.5			
Storm Surge (m)	0.4	0.54	0.7	1.0

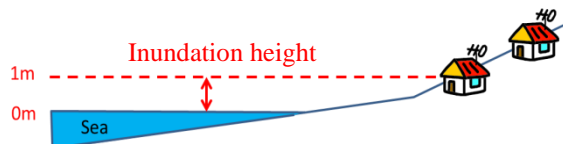


Figure 7.6 Concept of Extraction of Inundation Height from DEM

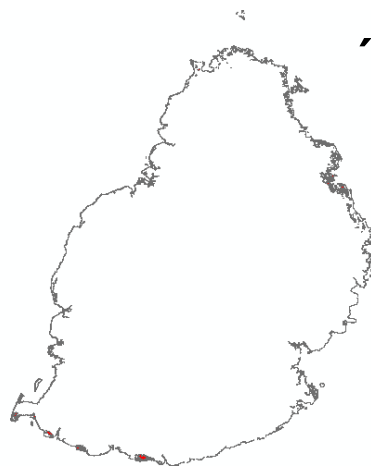


Figure 7.7 Output Result of Step 2(a)

Then, the extracted inundation area (output of step 2(a)) is intersected with the built-up area (output of step 1) to extract the overlaid section of these two results.

<sup>33</sup> Final Report of Disaster Risk Reduction Strategic Framework and Action Plan (DRR), Pg.90

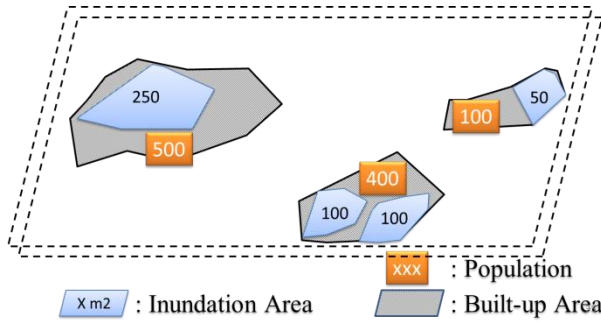


Figure 7.8 Concept of Overlaying the Inundation area and Built-up Area



Figure 7.9 Output Result of Step 2(b)

Output 2(b) shows the result of the population to be affected by coastal inundation by 2065. However, this result can be visualized to make the output even clear and understandable. This process is conducted in the next step.

Step 3 Storing calculated proportional distribution of population to administrative area (VCA)

This step is undertaken to visualize the output result of step 2(b).

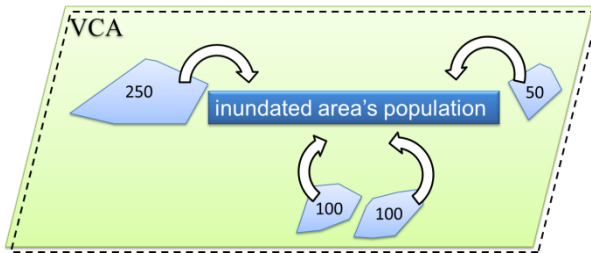


Figure 7.10 Concept of Storing Calculated Proportional Distribution of Population to Administrative Area (VCA)

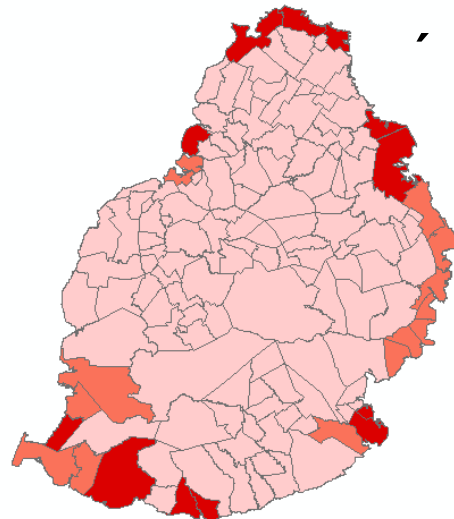


Figure 7.11 Output Result of Step 3

## 8. Setback Distance Analysis with Time-series in Coastal Zone

Further analysis (micro analysis) of each VCA is based on the result of the macro analysis.

### a. Steps and Analysis Method

The basic flow for the micro analysis is as below. Figure below shows the images of the micro analysis by ArcGIS.

Table 8.1: Basic flow of the Micro Analysis

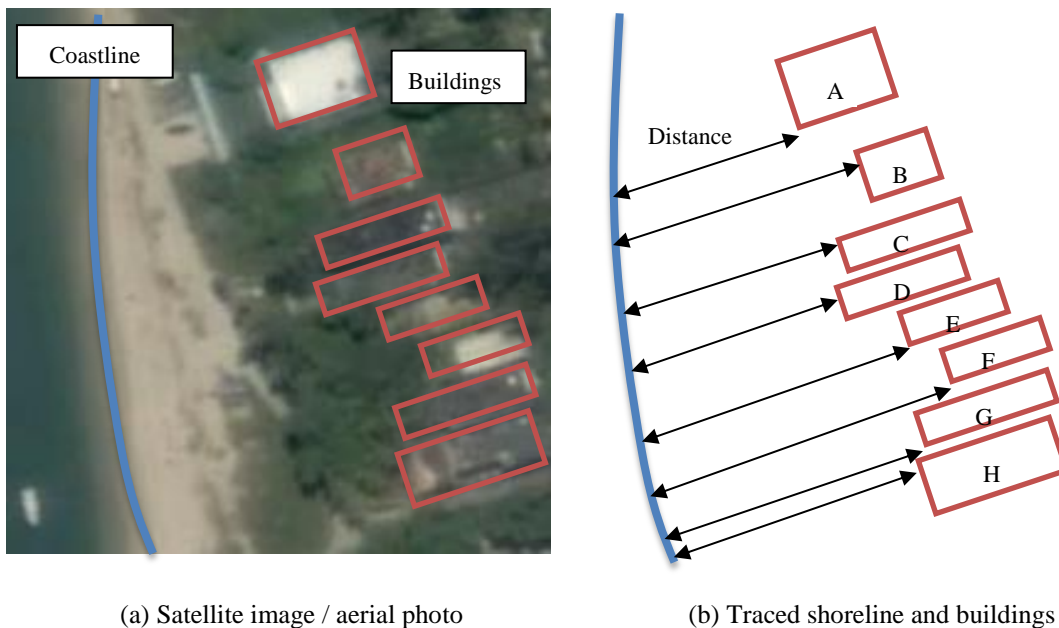
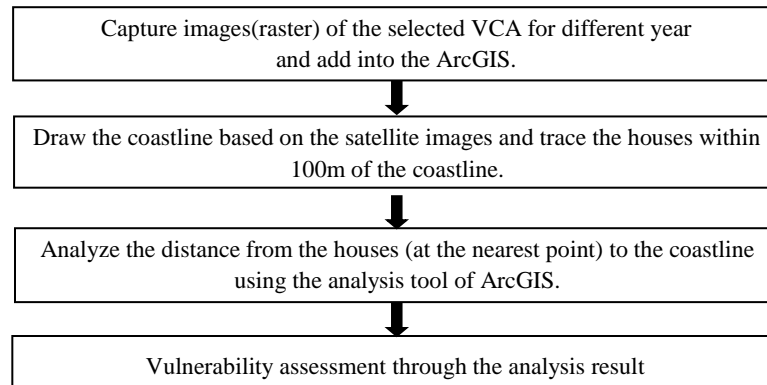


Figure 8.1: Images of Micro Analysis using ArcGIS

The images (raster data) can be classified into two types as mentioned below;

- 1) Satellite images (Google Earth Pro, World View 3 etc)
- 2) Aerial photo

The images acquired for this analysis as mentioned in the table below.

Table 8.2: Acquired Images (Raster Data)

VCA \ Year	1991 (Aerial)	2003 (Google)	2011 (Google)	2015 (Google)
Baie de Tombeau	○	×	○*	○
Poste de Flacq	×	×	○	○
Grand Baie	○	○	○	○
Roches Noires	○	○	○	○

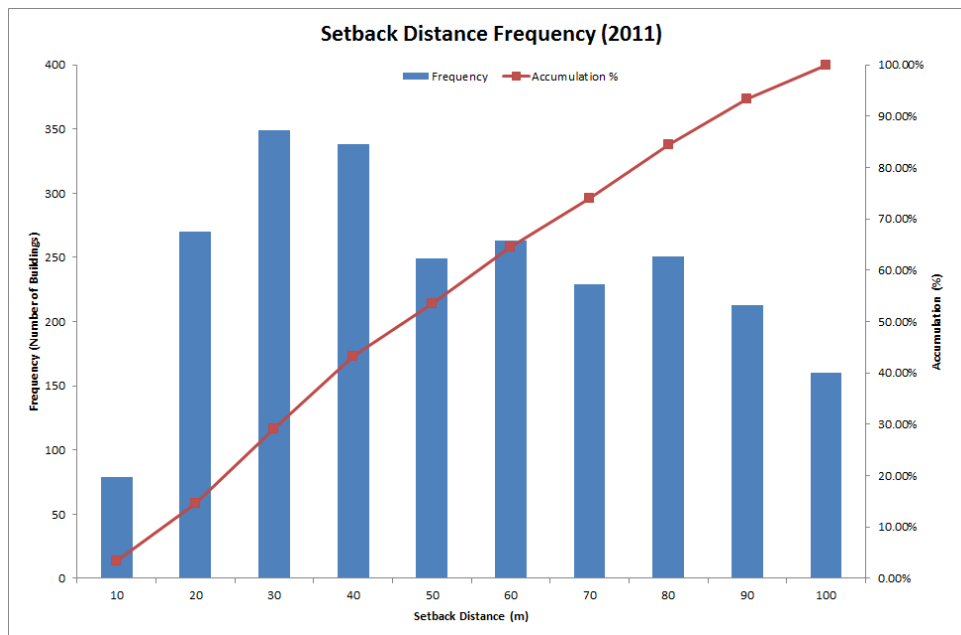
○: Available, ×: Unavailable, Aerial : Aerial photo, Google : Google Earth Pro

\* Satellite data of 2012 was used instead of 2011

**b. Result of Setback Distance Analysis**

**A) Setback distance and number of buildings whole prioritized coastal area by year**

The micro analysis is undertaken using the available data shown in table above. The figure below shows the frequency of the buildings from the four VCA (Baie de Tombeau, Poste de Flacq and Roches Noires) in 2011 and 2015



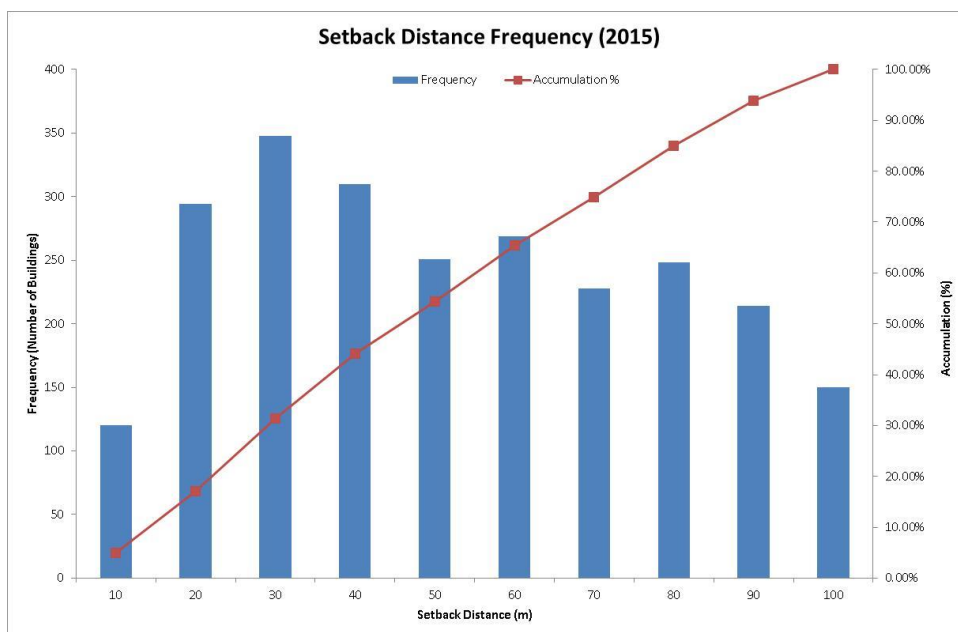


Figure 8.2: Frequency of the Buildings in 2011 and 2015

The highest number of buildings in 2011 distributed within 20~30m (349 building) and the lowest number of buildings distributed within 0~10m (79 buildings). 29% of the buildings which is constructed within 100m are distributed within 30m from the coastline.

The highest number of buildings in 2015 distributed within 20~30m (348 building) and the lowest number of buildings distributed within 0~10m (120 buildings). 31% of the buildings which is constructed within 100m are distributed within 30m from the coastline.

The figure above shows that the buildings within 0~20m from the coastline have been increasing from 2011 to 2015. However, the buildings within 30~40m have been decreasing since 2011. The buildings constructed within the 30m have been increasing from 698 (2011) to 762 (2015).

**B) Setback distance and number of buildings by VCA**

**Baie de Tombeau**

The figure below shows the frequency of the buildings from the coastline for 2003, 2011 and 2015 in Baie de Tombeau.

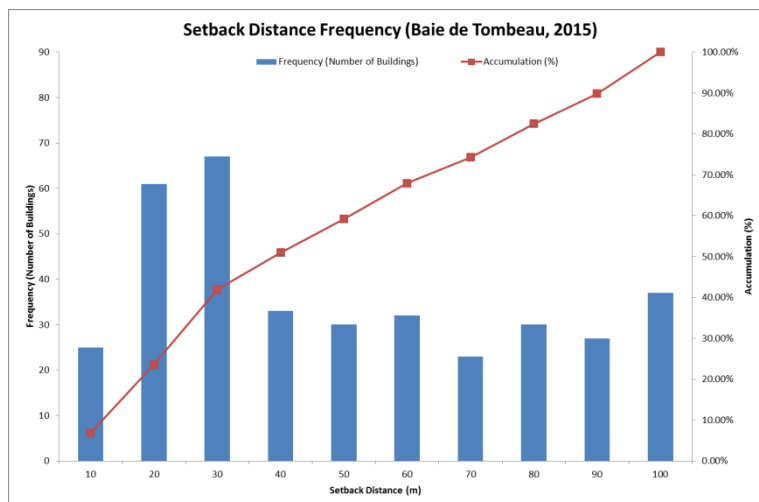
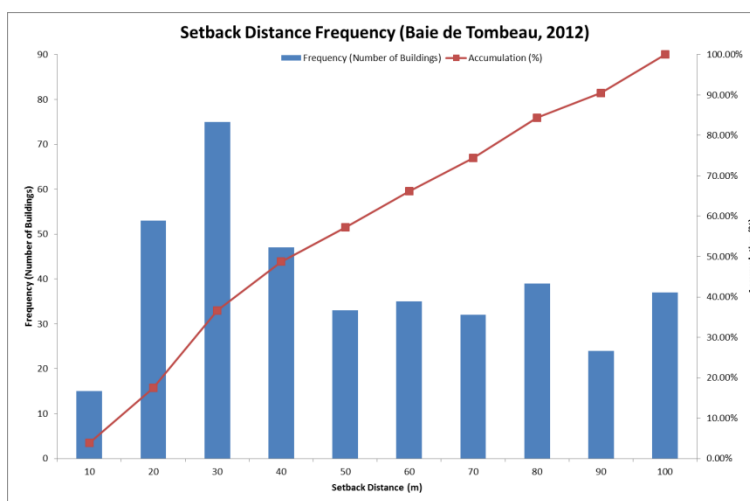
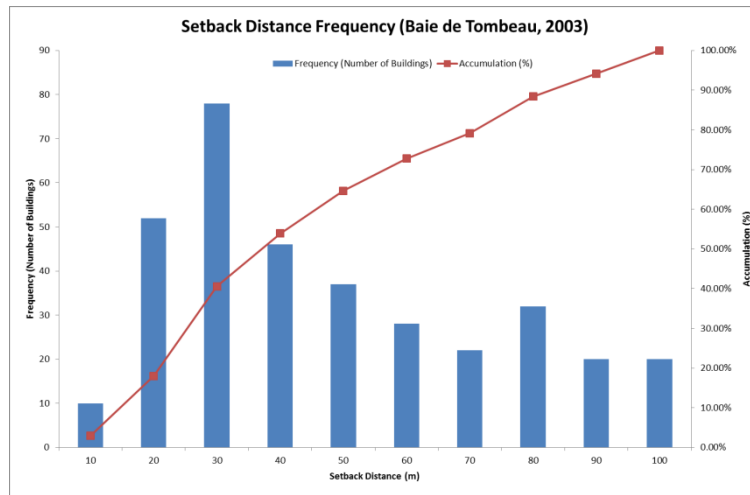


Figure 8.3: Frequency of the Buildings in Baie de Tombeau

The figure above shows that the buildings constructed within 30m from the coastline have been increasing from 140 (2003) to 153 (2015) since 2003 to 2015 in Baie de Tombeau.

**Poste de Flacq**

The figure below shows the frequency of the buildings from the coastline for 2011 and 2015 in Poste de Flacq.

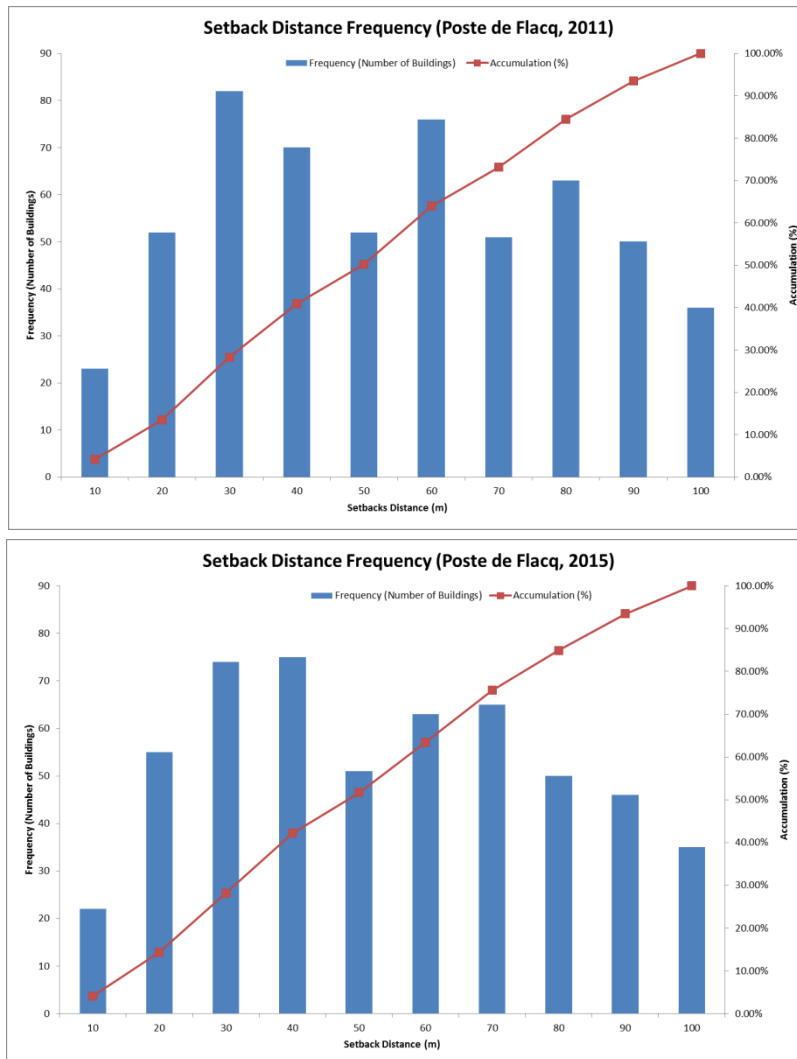


Figure 8.4: Frequency of the Buildings in Poste de Flacq

The figure above shows that the buildings constructed within 30m from the coastline have been decreasing from 157 (2011) to 151 (2015) in Poste de Flacq.

**Grand Baie**

The figure below shows the frequency of the buildings from the coastline for 2011 and 2015 in Grand Baie.



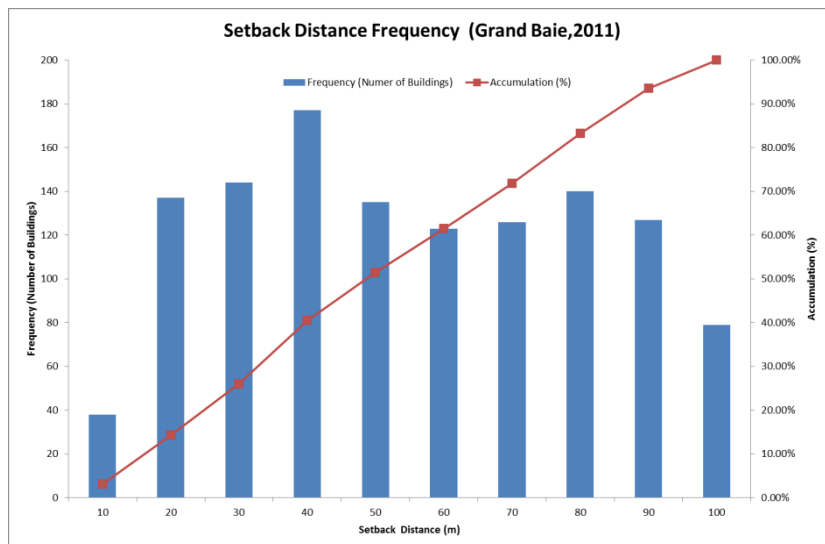
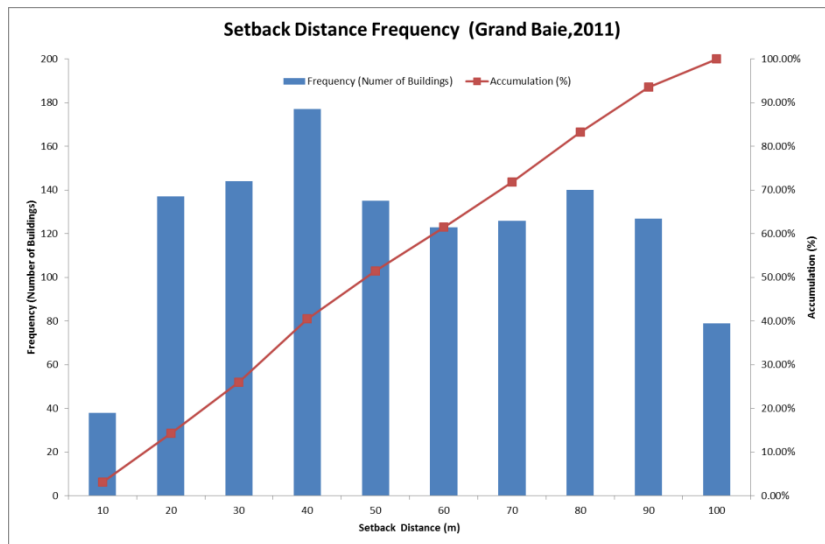


Figure 8.5: Frequency of the Buildings in Grand Baie

The figure above shows that the buildings constructed within 30m from the coastline have been increasing from 319 (2011) to 389 (2015) in Grand Baie.

**Roches Noires**

The figure below shows the frequency of the buildings from the coastline for 2006, 2011 and 2015 in Roches Noires.

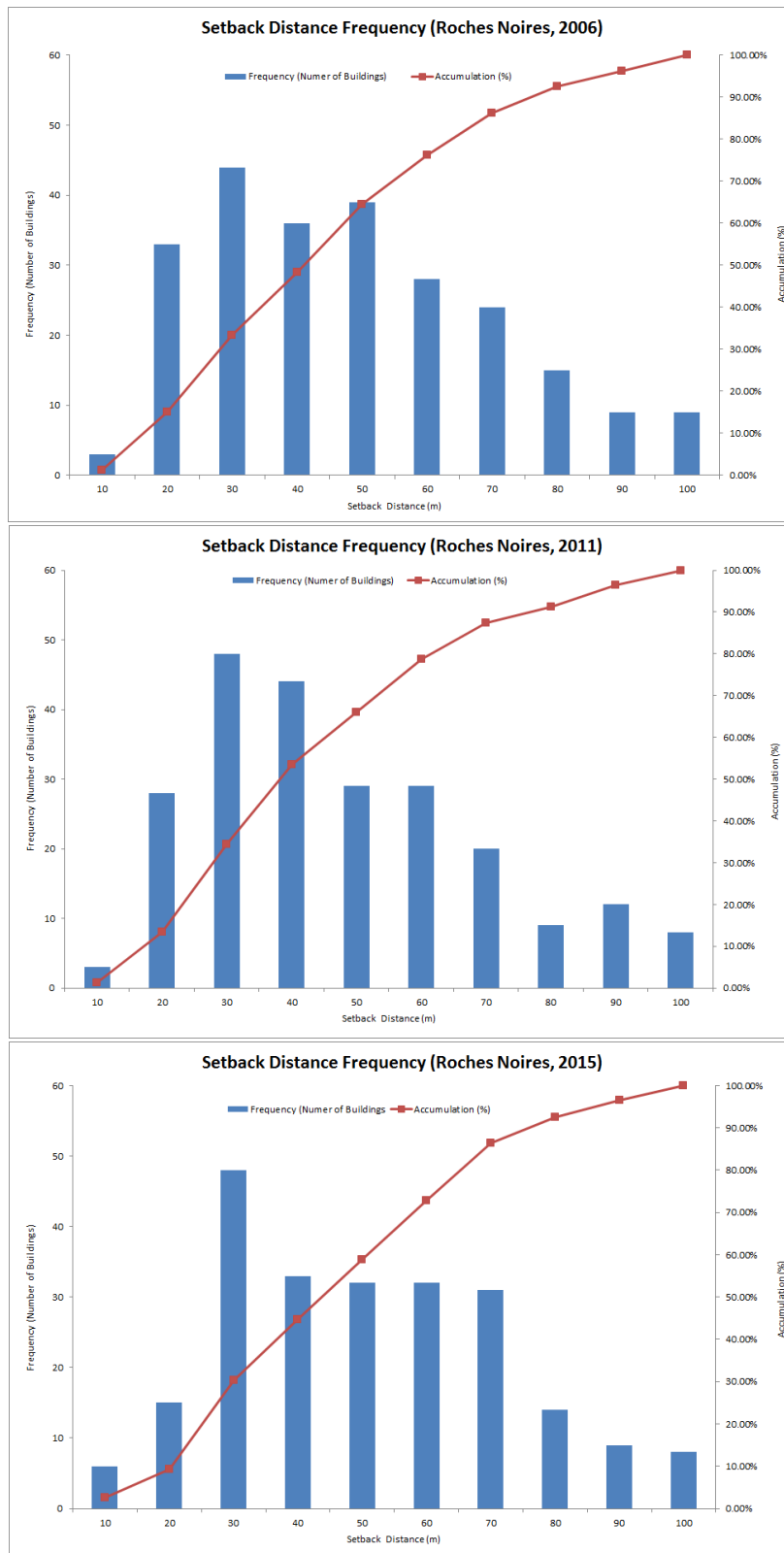


Figure 8.6: Frequency of the Buildings in Roches Noires

The figure above shows that the buildings constructed within 30m from the coastline have been decreasing from 80 (2006) to 69 (2015) in Roches Noires.

## 9. Recommendation for Mainstreaming the Setback Guideline into the Policies

### a. Monitoring

The items for monitoring are described in the Technical Guideline (Volume III) of JICA project<sup>34</sup>.

### b. Setting of the setback

Setback distance is set on the basis of the available information at the time for a period of 20, 50 and 100 years. Factor of long-term variation, short-term fluctuations effects of climate change and the impact of development shall be considered.

#### i. Long-term variation

Long-term variations are considered a phenomenon occurring under a predominantly natural condition in Mauritius which is assumed to continue in the future based on the change over the past 50 years. However, it is necessary to verify whether the same conditions have previously been recorded.

#### ii. Short-term fluctuations

Short-term fluctuations are mainly caused by the cyclone. The amount of erosion is difficult to be estimated as it only occurs rarely. However, there was a record of erosion during the cyclone Carol occurred in 1960. Continuous observation of the cyclone in the future is required to achieve a higher accuracy of prediction.

#### iii. Effects of climate change

Erosion due to sea level rise, the effect of degradation of coral due to increase in sea temperatures and the influence of the change in the intensity of the cyclone has been pointed out as the effects of climate change.

Although there is Bruun Rule which corresponding to the amount of increase, there is a problem in its adaptability. If sea level rises becomes about 0.1m in next 10 years, and the relation between sea level rise and erosion amount becomes 100 times, erosion will be 10m. If this relation can be secured, prediction of the formula can be justified. The validation of monitoring amount shall be made followed by the assumption of coefficient.

For the increase in degradation of coral and its impact of ocean temperature, since there is not enough study has been made. It is necessary to analyze the degradation situation of coral.

With regard to the influence of the cyclone, the influence to the erosion and accumulation condition of the sand is not clear without the impact of climate change. Therefore, estimation shall be made the in relation of erosion and recovery during the cyclone. At present, it is difficult

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<sup>34</sup> The Project for Capacity Development on Coastal Protection and Rehabilitation in the Republic of Mauritius

to distinguish between short-term variations because of the insufficient amount of data.

#### **iv. Impact of development**

The impact of coral harvesting recorded at the past, but it was abandoned. It can be observed at Flic en Flac. Harvesting seagrass along boat routes and anchorage maintenance is also assumed as the reason of erosion. This can be assumed based on past cases.

#### **v. Setback period**

To configure the setback, it is necessary to set the period, such as 20, 50 and 100 years. As long as the review will be made in 20 years, it is sufficient to keep the value of 30m. Excluding some coast, longer setback for longer period shall be applied such as 50m at 50 years or 100m at 100 years. Special attention shall be made on the effect of coral degradation.

##### **c. Setting of HWM**

In the current provisions, HWM value is set at the lease contract time. Therefore, HWM shall be set before the determination of setback and its value shall be practical. The validity of HWM shall be considered and set them into the Guideline.

Consideration of the fact that the beach topography, tidal and wave launch is varied, the practical value shall be applied. For example, (1) topographical survey of HWM at spring tide after the cyclone by using the GPS, and smoothed line to the coast line direction, (2) survey at every contract period, and smoothed line to the coast line direction, can be considered. Considering the past record ability of MHL, benefit-deficit analysis shall be examined and project into guidelines.

If the coasts that are short-term accumulation expected to be temporary, and since there are likely to be eroded in the future, HWM shall be set after the consideration of long-term balance. At least 50 years monitoring is required to verify whether it is stable.

##### **d. Set back management**

Monitoring shall be done every year regularly on the change of HWM, management of facilities inside of the setback area and to implement the review of the setback in every 20 years.

##### **e. Consideration for the existing development and retrofitting**

It will be a need to assess the existing development and the retrofitting in order to address the welfare of coastal communities. New developments would be subject to new regulations, which need to be very clear stated in the form of a series of Planning Policy Guidelines and Coastal Planning policies. It can ensure safety of coastal communities and climate change development designs which will provide additional safety to coastal communities.

## 10. Calculation for Setback for Coastal Erosion<sup>35</sup>

### a. Sand Beach

The setback amount for eroded sand beach is configured as summation of the amount of erosion during a certain period, the amount of erosion which is caused by strong wave such as cyclones in that period, and the erosion due to the SLR (sea level rise) is anticipated in future which is described as following.

Amount of setback = Amount of erosion for a long period + Amount of erosion by temporally event (i.e. extreme weather conditions such as cyclones ) + Erosion amount due to SLR

There are several proposed equations to estimate the amount of erosion due to the SLR. Among these, the equation proposed by Per Bruun is applied generally. The equation is as follows.

$$E=C \times S,$$

Where, E: Erosion amount due to the SLR, C: coefficient of beach characteristic and S: amount of SLR.

#### Example: Baie du Tombeau

The rate of the SLR from 1987 to 2011 is about 3.9mm/year in average, and the coefficient of C, which is related with the inverse of sea-bottom slope and transportation area of sediments, is set as 10 by the mean sea-bottom slope in Mauritius. The erosion amount due to the SLR, therefore, is calculated as 1.6 m by multiplying averaged erosion rate of 3.2mm/year, the coefficient of 10, and the period of 50years ( $E=10 \times 3.9\text{mm/year} \times 50\text{years}=2\text{m}$ ).

The amount of setback becomes 20m if the period is assumed 50 years, the erosion rate of 0.1m, and temporally erosion at the maximum caused by Cyclone Carol of 13m. Then the amount is under the present value of 30m.

$$\text{Amount of setback} = 0.1 \times 50 + 13 + 2 = 20\text{m}$$

### b. Cliff (Albion)

The setback line will be determined considering the estimation of cliff erosion speed, the life time of houses or structures, the slope area of the cliff and horizontal area. The most important is the slope area and it should be analysed based on the site inspection and aerial photos. From the preliminary site investigation, two areas can be taken as shown in. The first is the slope area where the rock is weathered and the cave is formed. The second is the horizontal area where estimated from the slope stability.

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<sup>35</sup> The Project for Capacity Development on Coastal Protection and Rehabilitation in the Republic of Mauritius (JICA, 2015)

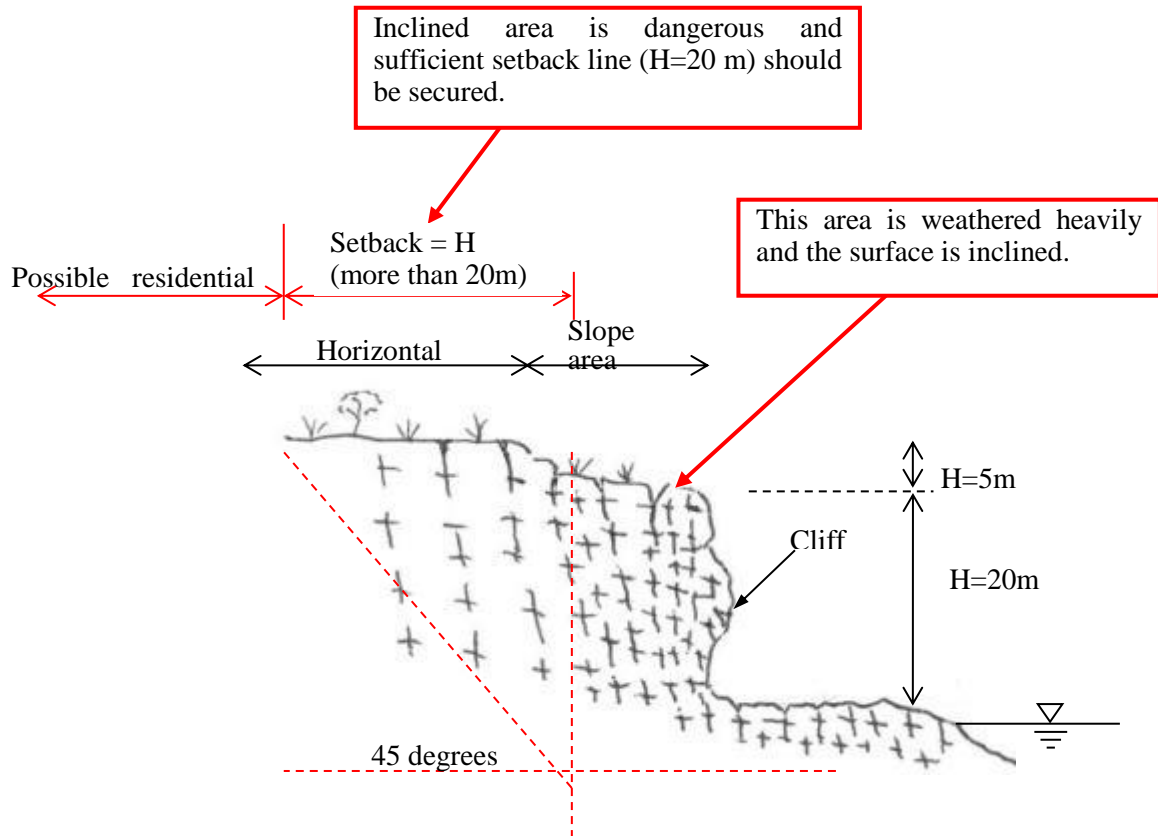


Figure 10.1: Image of the Setback Line (draft)

Based on the site inspection results, a preliminary examination of the setback line was conducted considering the facts that the existing cliff has been weathered, forming some caves, and the maximum stable degree (45 degree). A supplemental investigation will be conducted to analyze the existing conditions in details and then the final setback line will be determined. Figure 10.1 illustrates the image of the setback line.

Plateau behind coastal cliff behind has been used as a residential area and sugar cane fields mainly. There is a plan for future development in the hinterland at the north of lighthouse. The setback line of important public facilities has to be decided in considering the long term cliff erosion and corruption. The long term erosion is estimated 5m if the erosion speed is assumed as 5cm/y of basalt from experience and 100 years of service period. Then the setback line becomes as follows.

Recommendations: use 5cm /yr as an example. Further investigations required for Mauritius, to define parameters required-to elaborate

$$\text{Minimum Setback Line} = \text{Slope Area} + \text{Horizontal Area} + 5\text{m}$$


The minimum setback is estimated from the limited information at present. It becomes 65m in total if the slope area is 30m, the horizontal area is 30m of 30m high cliff and erosion is 5m. It is comparable to the Pas Geometriques of 81m if a margin is considered.

The actual figure can be decided from the precise topographic map. At present the contour

interval of the map is 10 in Mauritius. It is difficult to estimate the ground height of the cliff and the survey is necessary along the coast.

## 11. Field survey for data collection of the building attribute and disaster record

### Basic Information

Purpose	To collect the additional data for the vulnerability assessment	
Method	1) Interview	2) Visual observation
Item of survey	1) Building year 2) Type of building 3) No. of storeys	4) Type of wall and roof material 5) Disaster record 6) Extent of damage
Item	1) Map 2) Survey sheet	3) GPS 4) Measuring tape
Time (Trial)	10 <sup>th</sup> December 10:00 ~ 12:00 (2 groups)	
Surveyor (Trial)	1) Mr. I. Cheenacunnan 2) Mr. A.K. Dhoomun	3) Mr. Yoshimizu GONAI 4) Mr. Makoto TOKUDA
Area	Baie du Tombeau (100m within coastal area)	
No. of buildings	364 buildings*	
Result of the survey	1) Total surveyed buildings = 126 buildings 2) Surveyed buildings with complete information = 3) Surveyed buildings with partial information	
Photos		

\* based on building traced by satellite images

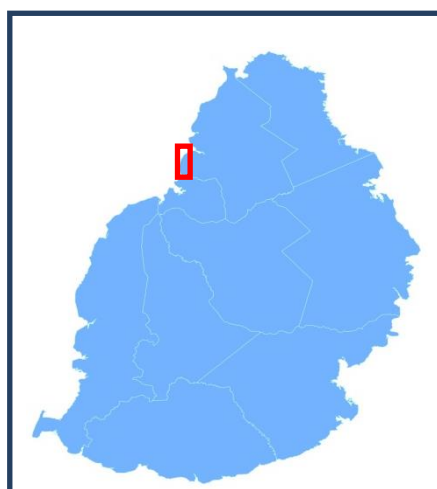




Figure : Study Area, Baie du Tombeau in red box

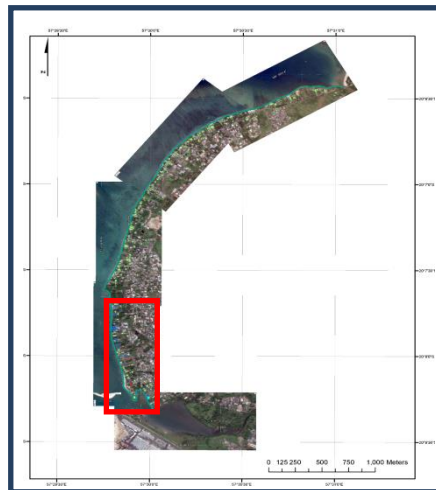


Figure : Baie du Tombeau Area

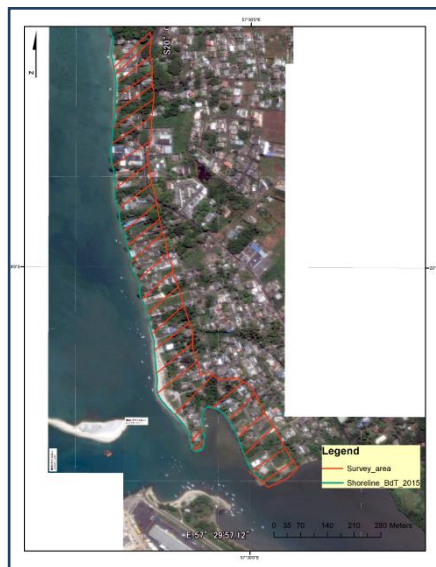


Figure : Area Surveyed in Baie du Tombeau

The table below shows the type and number of buildings situated within 30m or more than 30m from the shoreline. 27 out of 69 principal residences are situated within 30m from the shoreline. One of the column is marked unknown because those buildings were unoccupied during the time the survey was carried.

Shoreline Proximity	Under Construction and/or not inhabited	Principal Residence	Misc *	Unknown	Grand Total
More than 30m from Shoreline	9	42	10	14	75

Within 30m from shoreline	4	27	16	2	49
<b>Grand Total</b>	<b>13</b>	<b>69</b>	<b>26</b>	<b>16</b>	<b>124</b>

Table : Type and Number of buildings located within 30m or more from shoreline

The Table below shows the type and number of buildings situated within 30m or more than 30m from the shoreline, affected or not by inundation. Among the buildings surveyed, 2 principal residences situated within 30m from the shoreline are considered at risk to coastal inundation while 8 located more than 30m away were reported as being affected by inundation.

Shoreline Proximity	Under Construction and/or not inhabited	Principal Residence	Misc*	Unknown	Grand Total
<b>More than 30m from shoreline</b>	<b>9</b>	<b>42</b>	<b>10</b>	<b>14</b>	<b>75</b>
Non Inundated		18	2		20
Inundated	1	8	1		10
Unknown	8	16	7	14	45
<b>Within 30m from shoreline</b>	<b>4</b>	<b>27</b>	<b>16</b>	<b>2</b>	<b>49</b>
Non Inundated		13	8		21
Inundated		2	1		3
Unknown	4	12	7	2	25
<b>Grand Total</b>	<b>13</b>	<b>69</b>	<b>26</b>	<b>16</b>	<b>124</b>

Table : Number and type of buildings situated within 30m or more from shoreline prone to inundation

\*Misc: Hotel, Guest House, Tourist residence, Clinic, Commercial, Other non-residential Building

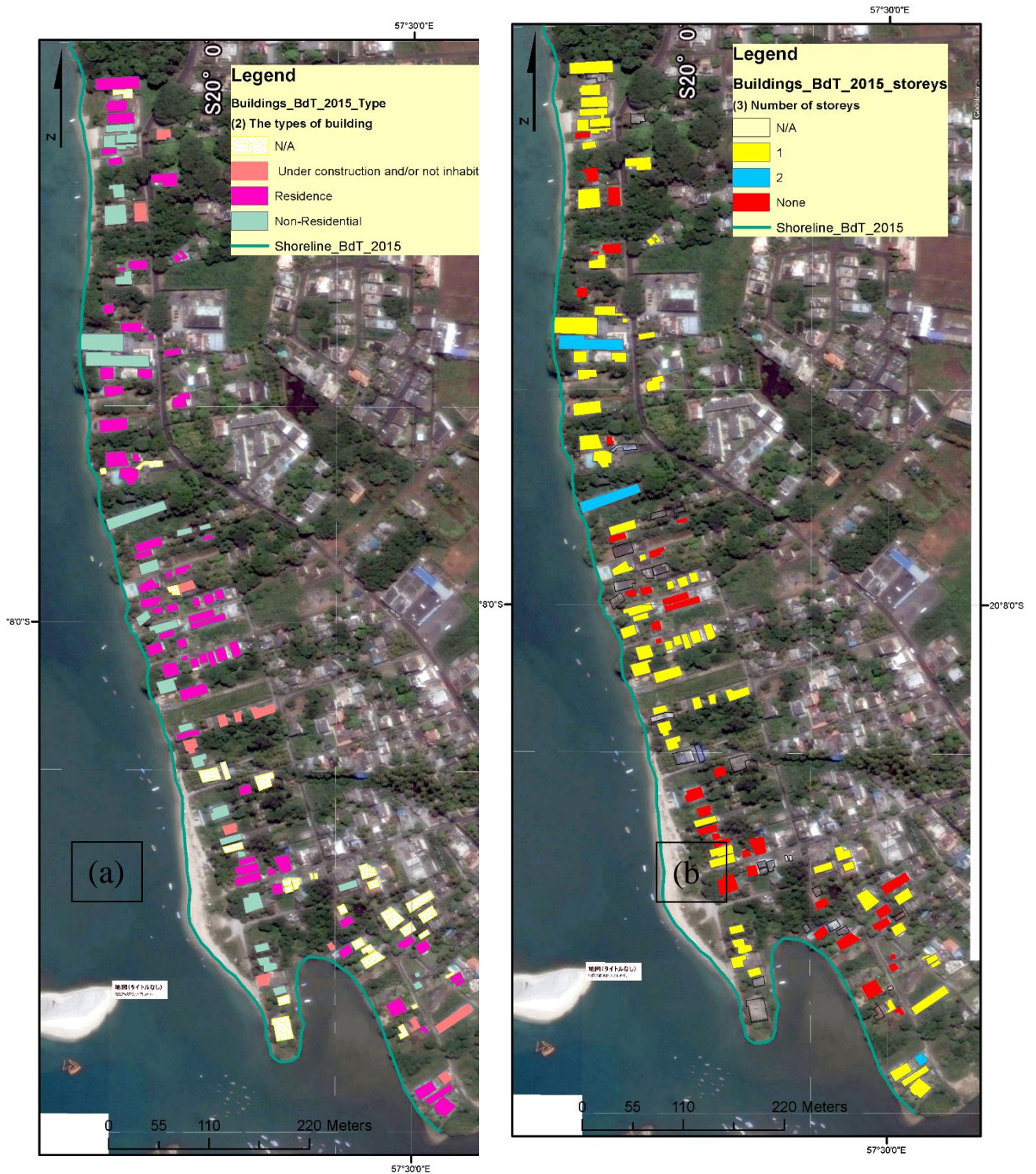


Figure : (a) Type of building within 100 m from shoreline & (b) Number of storeys for each of these buildings.

Buildings situated within 100m from the shoreline were surveyed. Figure (a) shows the type of buildings situated in this zone and figure (b) shows the number of storey of each of these buildings.



Figure : Buildings situated within 100m from shoreline and being affected or not by inundation

The figure above shows the buildings affected or not by inundation. The buildings symbolized with red are the ones reported as being prone to inundation.