THE REPUBLIC OF MAURITIUS
MINISTRY OF ENVIRONMENT, SUSTANAIBLE
DEVELOPMENT, DISASTER AND BEACH MANAGEMENT
(MOESDDBM)

THE PROJECT FOR CAPACITY DEVELOPMENT ON COASTAL PROTECTION AND REHABILITATION IN THE REPUBLIC OF MAURITIUS

FINAL REPORT

MAIN REPORT

(Volume 1)

June 2015

JAPAN INTERNATIONAL COOPERATION AGENCY

KOKUSAI KOGYO CO., LTD.
NIPPON KOEI CO., LTD.
CENTRAL CONSULTANT INC.
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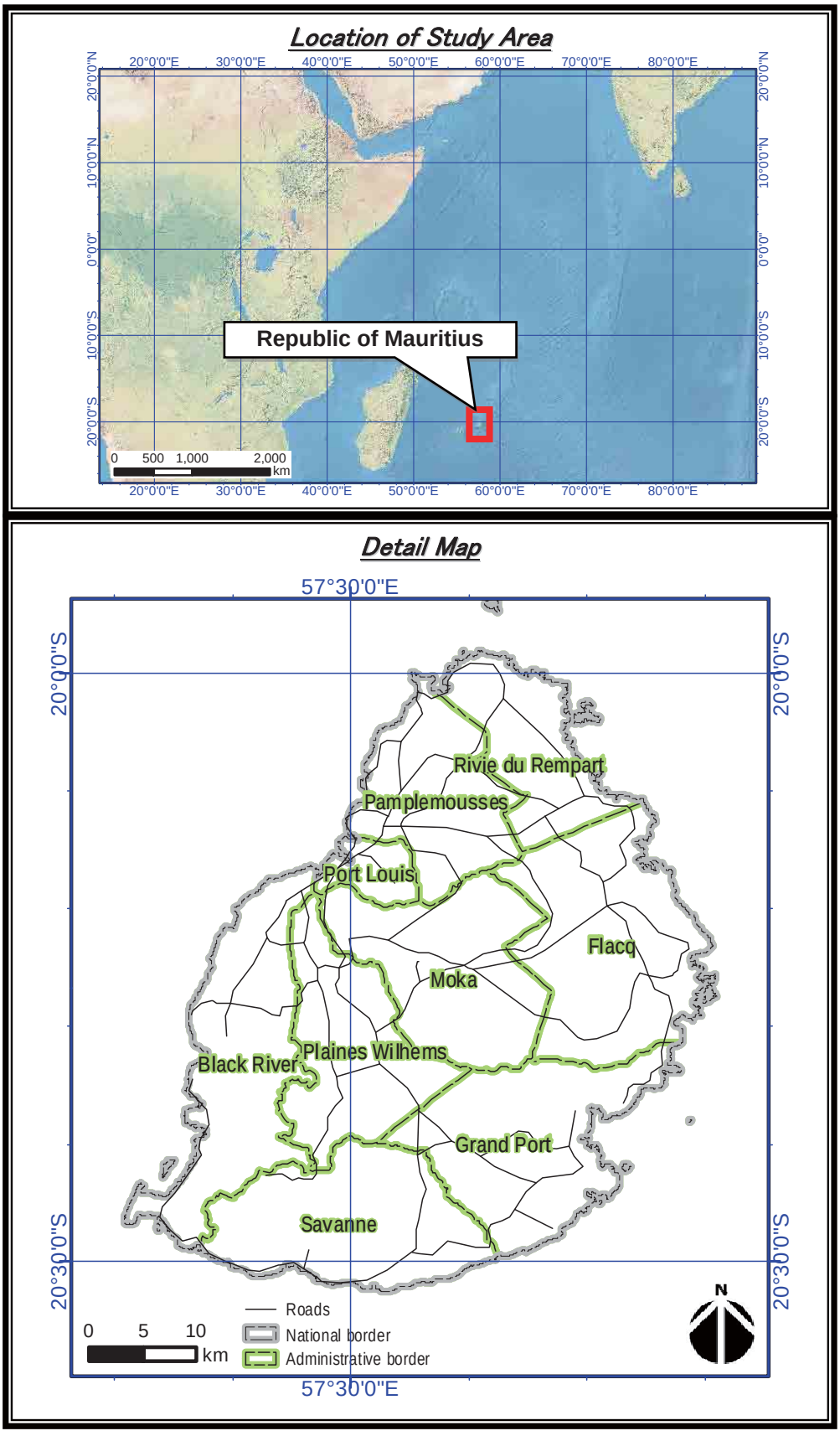

Location Map

Rate of Currency Translation

1 USD = 35.230 Rs

= 124.11 JPY

100 Rs = 2.760 USD

= 342.56 JPY

Rs: Mauritius Rupee

As of June 1st, 2015

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Abbreviations

Abbreviations	English
AAP	Africa Adaptation Programme
AC	Advisory Committee
ACB	Acropora Branching
AF	Adaptation Fund
AFD	Agence Française de Développement
AFP	Adaptation Fund Programme
AFRC	Albion Fisheries Research Centre
AP	Absorption Pit
APHA	American Public Health Association
BA	Building Act
BA	Beach Authority
BLUPG	The Building and Land Use Permit Guide
BOD	Biochemical Oxygen Demand
C/P	Counterpart
CA	Capacity Assessment
CAB	Cabinet
CACI	Compact Airborne Spectrographic Imager
CADMAC	Climate Change Adaptation and Disaster Management Committee
CBR	Cost Benefit Ratio
CC	Crisis Committee
CCD	Climate Change Division
CACI	Climate Change Information Centre
CD	Capacity Development
CD	Chart Datum
CEB	The Central Electricity Board
CDEMA	Caribbean Disaster Emergency Management Agency
CF	Coral Foliose
CIRIA	Construction Industry Research and Information Association
CM	Coral Massive
COD	Chemical Oxygen Demand
CONDC	The Cyclone and Other Natural Disasters Committee
CONDS	Cyclone and Other Natural Disasters Scheme
CSO	Central Statistics Office
CVM	Contingent Valuation Method
CWA	The Central Water Authority
DB	Data Base
DC	District Council
DC	Dead Coral
DEM	Digital Elevation Model
DFR	Draft Final Report
DL	Datum Line
DO	Dissolved Oxygen
DRR	Disaster Risk Reduction
ECMWF	European Centre for Medium-Range Weather Forecasts

Abbreviations	English
E.Coli	Escherichia coli
EIA	Environment Impact Assessment
EIRR	Economic Internal Rate of Return
EMoP	Environment Monitoring Plan
EPA	Environment Protection Act
EPZ	Export Processing Zone
ESA	Environmental l y Sensitive Area
EU	European Union
F/S	Feasibility Study
FAS	First Aid Service
FC	Feacal Coliform
Fs	Safety Factor/Factor of Safety
GDP	Gross Domestic Product
GIS	Government Information Service
GIS	Geographic Information System
GL	Ground Level
GPS	Global Positioning System
GR	Grand River
HFA	Hyogo Framework for Action
HWL	High Water Level
HWM	High Water Mark
IC/R	Inception Report
ICZM	Integrated Coastal Zone Management
IEC	Information, Education, and Communication
IOC(COI)	Indian Ocean Commission (Commission de l'Océan Indien)
ISO	International Organization for Standardization
JBIC	Japan Bank for International Cooperation
JCG	JICA Coordination Group
JET	JICA Expert Team
JICA	Japan International Cooperation Agency
JICE	Japan International Corporation Center
JTWC	Joint Typhoon Warning Center
K	Potassium
K-N	Kjeldahl Nitrogen
LEU	Living Environment Unit
LIT	Line intercept transects
LGA	Local Government Act, 2003
LMHTF	Le Morne Heritage Trust Fund
LMU	Landslide Management Unit
LWL	Low Water Level
M/M	Minutes of Meeting
Mauritius	The Republic of Mauritius
MBC	Mauritius Broadcasting Corporation
MEHR	Ministry of Education and Human Resources
Mg	Magnesium

Abbreviations	English
MGCW	Ministry of Gender Equality, Child Development and Family Welfare
MHL	Ministry of Housing and Lands
MHQL	Ministry of Health and Quality of Life
MID	Maurice Ile Durable
MLG	Ministry of Local Government & Outer Islands
MMS	Mauritius Meteorological Services
MoAFS	Ministry of Agroindustry and Food Security
MoESD	Ministry of Environment and Sustainable Development
MOESDDBM*	Ministry of Environment, Sustainable Development, Disaster and Beach Management (*Former MoESD)
MoF	Ministry of Fisheries (current MoOEMRFSO)
MoFED	Ministry of Finance and Economic Development
MoFR	Ministry of Fishery and Rodrigues
MOI	Mauritius Oceanography Institute
MoOEMRFSO	Ministry of Ocean Economy, Marine Resources, Fisheries, Shipping and Outer Island
MPA	Marine Protected Area
MPI	Ministry of Public Infrastructure, National Development Unit, Land Transport and Shipping
MPN	Most Probable Number
MSL	Mean Sea Level
MSS	Ministry of Social Security, National Solidarity and Reform Institutions
MTEF	Medium-Term Expenditure Framework
MTL	Ministry of Tourism and Leisure
MTSRT	Ministry of Tertiary Education, Science, Research and Technology
MUR	Mauritius Rupee
Na	Sodium
NCAR	National Center for Atmospheric Research
NCCAPF	National Climate Change Adaptation Policy Framework
NCEP	National Centers for Atmospheric Prediction
NCG	National Coastal Guard
NDOCC	National Disaster and Operations Coordination Centre
NDRRMC	National Disaster Risk Reduction and Management Committee
NDS	National Development Strategy
NDU	National Development Unit
NEL	National Environmental Laboratory
NGO	Non-Governmental Organization
NH_4-N	Ammonia Nitrogen
NHDC	National Housing Development Corporation
NO_2-N	Nitrite Nitrogen
NO_3-N	Nitrate Nitrogen
NPV	Net Present Value
NTU	Nephelometric Turbidity Unit
ODA	Official Development Assistance
OJT	On the Job Training
OPS	Outline Planning Schemes

Abbreviations	English
P.Fs	Planning/Designed Factor of Safety
P/R	Progress Report
PB	Public Beach
PBB	Programme-Based Budgeting
PDA	Planning and Development Act
PEFA	Public Expenditure and Financial Accountability
PER	Preliminary Environmental Report
PFM	Public Financial Management
PIANC	World Association for Waterborne Transport Infrastructure (former Permanent International Association of Navigation Congresses)
PIU	Planning and Implementation Units
PL	Pit Latrine
PM	Project Manager
PO_4-P	Phosphate-Phosphorus
PMO	Prime Minister's Office
PMS	Performance Management System
PPG	Planning Policy Guidance
PS	Permanent Secretary
PVC	Polyvinyl Chloride
QGIS	Quantum GIS
R/D	Record of Discussion
RN-COI	Risques Naturels de la Commission de l'Océan Indien
SA	Sand
SAREC	Swedish Agency for Research Cooperation with Developing Countries
SC	Steering Committee
SC	Spot Check
SC	Soft Coral
SCOR	Scientific Committee on Oceanic Research
SIDS	Small Island Developing States
SO4	Sulphate
SS	Sewerage System
SS	Suspended Solid
SSPA	Segridad Salud Proteccion Ambiental
SST	Sea Surface Temperature
ST	Septic Tank
SWAN	Simulating Waves Nearshore
TA	Turf Algae
TAS	Treasury Accounting System
TC	Total Colifrom
TC	Technical Committee
TCPA	Town and Country Planning Act
TDS	Total Dissolved Solid
The Disasters Scheme	The Cyclone and Other Natural Disasters Scheme
The Project	The Project for Capacity Development on Coastal Protection and Rehabilitation in the Republic of Mauritius

Abbreviations	English
TICAD IV	The Fourth Tokyo International Conference on African Development
TICAD V	Fifth Tokyo International Conference on African Development
T-N	Total Nitrogen
TOR	Terms of Reference
T-P	Total Phosphorus
TSHD	Trailing Suction Hopper Dredger
TSS	Total Suspended Solid
UNDP	The United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization -
UoM	University of Mauritius
USD	United States Dollar
UTM	Universal Transverse Mercator
VAT	Value Added Tax
VCA	Village Council Area
VMCA	Voluntary Marine Conservation Area
WCDR	World Conference on Disaster Reduction
WGS	World Geodetic System
WMA	Wastewater Management Authority
WMO	World Meteorological Organization
WS	White Syndrome

Summary

The Project of Capacity Development on Coastal Protection and Rehabilitation in the Republic of Mauritius started in May 2012 according to the Minutes of Meeting agreed upon between the Ministry of Environment, Sustainable Development, Disaster and Beach Management (hereinafter referred to as MOESDDBM) of the Republic of Mauritius and the Japan International Cooperation Agency in 2011. This report is the Final Report which covers the results of the project.

In order to properly maintain the coastal zone in Mauritius, the outcomes of the project are;

1) The affected sites were identified through baseline survey.
2) The coastal conservation plans in the main island of Mauritius were formulated.
3) The effectiveness of the coastal conservation plans were validated through the demonstration projects.
4) The technical capacity of the staff in the MOESDDBM and other administrations is enhanced.

The project site is the main island of Mauritius. The Environment Unit in Rodrigues received technical advice.

The project was divided into four components: Component 1 “Baseline Survey”, Component 2 “Formulation of Coastal Conservation Plans”, Component 3 “Implementation of Demonstration Projects” and Component 4 “Technical Transfer of Coastal Conservation Management”. The results are summarized as follows.

Natural and Social Conditions

Mauritius is a volcanic island with a total area of 1,860km^2. From north to south the distance is 60km and from east to west the distance is 50km. Most of the Mauritius is surrounded by coral reef. The total length of the coastal line is about 322km and the length of the coral reef is 150km and the area of the coral reef is 243km^2. The coast is classified into mainly three types; sandy coasts of coral with a narrow reefs, silt and pebble coasts with a wide reef and cliff coasts without a reef. The coral reef supplies beach sand and dissipates wave energy.

The tide is dominated by the semidiurnal tide and the tidal difference of spring tide is 0.5m. The wave characteristics are classified into three types; high waves by cyclone from north to east, wind waves by southeast trade winds, long waves from southwest. The cyclones usually occur from December to March. Damage from cyclones have occurred in Mauritius in 1982, 1931, 1960 (Carol), 1975 (Gervaise) and 1994 (Hollanda).

The population of Mauritius is about 1.3 million and the population density is about 600 per km^2. The primary industries of Mauritius are sugar, textiles, tourism and financial services. Tourism contributes to economic development and the beach is an important natural resource. The annual number of tourists is roughly one million and the average length of stay is approximately 10 days. The number of hotels currently in operation is 109 and the number of rooms is 12,000. The break-down of coastal land use is 76 km^2 (23 %) for vegetation, 52 km^2 (16%) for bungalows, 42 km^2 (13%) for hotels, 39 km^2 (12%) for public beaches, and 16 km^2 (5%) for coastal roads.

Coastal Disasters and Conservation

In the past, Cyclone Carol hit in 1960 and caused beach and cliff erosion along the coastline of Mauritius. The coastal erosion reached 13 m at its maximum. Gabions of 3.5km in length were installed after Cyclone Hollanda in 1994.

In 2003, after a detailed investigation, Baird pointed out that the sandy beach recovered after erosion. However, this was not the case of coral reef system, lagoon and beach were impacted by human activities. Based on the results, it is recommended that the coral reef and the dynamic beach are kept in natural conditions and the structural measures should be a last resort. Sand mining within the reef lagoon was banned in 2003.

The coastal zone is defined from the high water mark (HWM) to 1km landward and seaward in Mauritius. The land from the HWM to 81 m inland is called Pas Geometriques and is owned by the state. It is used both commercially and privately as a leasehold. The 30m inland from the HWM is the setback area where the construction of structures are regulated and there are no buildings. The setback before 2005 was 15 m and the existing buildings will need to be compliant with the new (from 2005) setback of 30 m when their lease comes up for renewal (generally 60 year leases). The structures for coastal protection need to gain an EIA license.

After 2006, the coastal protection measures are removing gabion revetments, constructing rock revetments, and nourishing sand. Structural measures have already been implemented to most of the necessary coasts. Rock revetments are large in order to go up against external forces. This however leads to coastal use problems including the environment and landscape.

The organizations for coastal conservation are the ICZM of MOESDDBM which is responsible for leading, managing and coordinating with related organizations in the coastal zone, MoHL which is responsible for land management, MoF which is responsible for the conservation of the reef environment, BA which is responsible for public beaches, MSS and MOI which are responsible for investigation and research MoTL, which is in charge of tourism development and other ministries.

Coastal Change

The coastal changes over 45 years were analyzed based on six different periods shown in aerial photos from 1967 to 2012. The target coast is the sandy beach of 13 sediment cells and becomes 67km in total. The eroded coast is 17 %, the accreted coast is 23% and the stable coast is 59% in total. Three sediment cells are eroded and seven cells are partly eroded and accreted. The sand budget in total is accreted. The short term changes are larger than the long term changes. The causes of coastal changes are cyclones and the degradation of corals and seagrasses on the erosion side, and growth of corals contributing to sand accretion.

Reef Environment

Coral reef has important functions for coastal conservation from being a source of beach sand to decreasing wave energy. The coverage of live coral was monitored at 44 points by the spot check method. The mean coverage was 27%. The long term changes of the coverage have been monitored by AFRC from 1998. The results show that the coverage at the fore reef decreased continuously from 50% to under 20% and at the back and shore reef it dropped to 10% or 20% due to the increase of sea surface temperatures in 2009.

Eutrophication of water is estimated as one of the causes of coral degradation. The condition is not well understand because of the low quality of water analysis. The field investigation shows that the coral coverage decreases with the increase of turbidity, chlorophyll a, nitrogen and phosphorus.

Formulation of Coastal Conservation Plans

For the coastal conservation plan, the strategy was formulated based on the problems derived from the baseline survey and the evaluation of coastal risks. There are a total of 58 coasts in Mauritius and among these 20 were chosen for the basic coastal study. For the selection of priority coasts in the coastal conservation plan, 14 were chosen from the 20 in the basic study. The coastal conservation plan includes the planning for coastal maintenance, reef environment and capacity development.

Coastal Conservation Strategy

The strategy proposed for coastal conservation is based on the basic study results and the related issues for three objectives; coastal protection, coastal development and environmental conservation. To help achieve these objectives, the following three points were taken into account.

- To maintain and make use of natural characteristics of the coast
- To build the abilities for natural and socio-economic changes in the future
- To integrate coastal management with the collaboration of stakeholders

Coastal Conservation Plan

The coastal conservation and maintenance plan for 14 priority coasts is formulated from the problems of the coast, classification of their characteristics and alternative measures.

In the coastal conservation plan, the principle is to keep the natural conditions through the setback and/or sand nourishment because the eroded coasts are limited from the baseline survey and the sandy beach is an important resource for tourism. The reef environment is also deteriorated. So conservation of the reef is included.

Sand nourishment is taken as a measure for coasts which are eroded as a whole. This is applicable for Mon Choisy. In this case the eroded volume is estimated at roughly $500m^3$/year which is feasible to implement without interfering with the beach use. Also, a combination of groynes is possible as was done at Pte. aux Cannoniers.

Sand recycling, coral farming or planting of seagrass will be applied depending on the causes and beach characteristics for the partly eroded and stable or accreted coast in total. If the erosion is partly caused by the disappearance of coral, seagrass and mangrove, sand recycling can be applied from the accreted area to the eroded area in the short term and rehabilitation of the coral, seagrass and/or mangroves will become a long term measure. This applies to the Bras d'Eau, Flic en Flac and Pte. d'Esny coasts. At Ile aux Cerfs, the problems are channel clogging and erosion at adjacent beaches caused by the topographic characteristics. The measures are sand dredging from the channel and sand recycling to the eroded beach. At Le Morne, the beach has eroded at one side and accreted at the other side by the jetty for anchorage. In this case, sand bypassing will be applied.

If the coastal changes are caused by cyclones or the degradation of coral or seagrass, it is necessary to apply the setback. From the existing information, the present setback of 30 m is reasonable. However, monitoring of changes to topographical features is required to make any necessary adjustments. In the project, the setback at cliff coast was studied at Albion as an example. The plans includes improvement or removing of vertical revetments to gentle revetments. The removal of facilities in the setback area is also proposed.

Coasts formed by silt or cobble with wide reefs are characterised by low-lying ground in the coastal area. These low-lying areas are considered to be at risk of wave run-up in the future due to high waves and/or sea level rise. As one of the measures, flexible revetment was proposed. It imitates the local topography and material. The applicability is demonstrated by the demonstration project at Grand Sable.

Coral, which is the source of sand and which acts to dissipate wave energy, is deteriorated by the increase of sea surface temperatures. In order to recover losses, coral farming is proposed by the improvement of water quality and the regulation of activities in lagoons.

During the formulation of coastal conservation plans, technical committees and meeting by working groups were held in order to develop the capacity of related organizations. The basic information for the plan is limited so improvements can be made by evaluation from the demonstration projects and continuous monitoring.

Coastal Maintenance Plan

For the maintenance of the coast, reprofiling beach scarp which is easily formed by cyclones is recommended for the earlier recovering and the security of the public. In the setback area, the improvement of the vertical revetment to decrease scouring and the impact to the adjacent beach is recommended. In addition, monitoring and management of illegal construction as well as removing sand from the beach during beach cleaning is recommended.

Reef Environment Conservation Plan

From the time series analysis, the coral patch and seagrass bed in lagoons are clearly related to the coastal changes of erosion and accretion. The coral condition in Mauritius changed after 2000 from “good” to “failure” according to the comprehensive evaluation. The causes are estimated to be eutrophication, sediment inflow, fishing and marine sports in lagoons, anthropogenic causes together with the biological factors (crown-of-thorns starfish, etc.), coral bleaching and rises in sea surface temperatures.

To solve these problems, an action plan is recommended. It includes monitoring the reef environment by aerial photo and sea truthing and water quality, analysing monitoring results, regulating human activities in a lagoon, controlling water quality in a lagoon, planting seagrass and coral farming. These activities will contribute to the rehabilitation of the reef environment and to the stability of beach.

Coastal Management Organization

For the planning of coastal management system, organization, information, education and communication, the ICZM framework was already proposed by Landell Mills (2009) and has been approved by the Mauritius government. Implementation should be the focus point as the problem is action. Issues relating to implementation are the capacity development of responsible officials through daily work, the exchange of information between related

organizations, and the creation of measures based on the characteristics of Mauritius.

Demonstration Projects

As a physical measure, flexible revetment made of sand and crushed stone (gravel) was proposed when taking into account the natural characteristics of the site, the coastal use, environment and landscape and the ease to cope with future changes such as sea level rises. In the project, the evaluation of the revetment and the capacity development were considered.

Grand Sable at the southeast was selected as the demonstration site of physical measures. Here the coast is low and the coastal road will easily suffer the impact of wave run-up and future sea level rise. The revetment plan is 400m long with the height at 2m and the width set at 10m with the slope at 1:5. A 240m portion was constructed from October to December 2013. For the capacity development, planning, designing and managing construction were carried out with the counterparts. For the residential agreement and future maintenance, a meeting of the council of local people as well as events were held.

The monitoring results after one year show that the gravel and sand mix is almost stable. The sand is partly transported alongshore to the north area without construction but it is not a serious problem. The beach has various uses including boat landings, functioning as a playground for children, and fishing. It is clean compared to the pre-construction state. The smell and water quality has improved. The local people monitor and clean the beach voluntarily. The results can be applied to the other coasts.

For the non-physical measures, the project was aimed at building consensus for the plan among the stakeholders, including the local residents. Pte. d'Esny at the southeast coast was selected as the site. Bungalows and houses are located along the coast as well as some hotels. Revetment and groynes were constructed for the prevention of coastal erosion in the past. The coast is accreted as a whole but partly eroded and the impacts of structures are expected.

Problems include the lease contract, the setback, the effects and impacts of existing structures, the mechanism of erosion and the conflict between individuals and overall conservation plans. Consensus building is required for the project.

The project direction and its proposed measures include rearrangement of existing structures and sand nourishment based on the erosion conditions and consultations with stakeholders. Several meetings with residents were held which proposed alternatives that took into account the opinions of lessees. However it is difficult to get everyone to agree on the same thing.

The main problem of consensus building for this plan is the removal of existing structures and showing unequivocally that there will be no impacts caused by the removal. It is necessary to show similar examples by monitoring and accumulation of data and to obtain the residents' understanding.

Technology Transfer

The project was conducted to improve the technical capacity and to obtain engineering knowledge required in practice. On the job training was carried out through the site survey, beach monitoring, data analysis, task analysis, planning and the implementation of demonstration projects. Related guidelines were also formulated. Seminars, workshops, training in Japan, and technology exchange were carried out in combination. They are

considered to be suitable for the conditions and the technical level in Mauritius.

The technical guidelines include natural and design conditions of coastal conservation works, designing and planning of coastal structures, monitoring of beach and coral conditions, analyzing water quality, coral farming and EIA for coastal protection.

The workshops were held for the coastal conservation plan with related organizations and residents to discuss the contents of the plan and to confirm the sites. Seminars were held to explain the outline of the project at the beginning and to disseminate the results at the end. The counterparts attended a seminar in Seychelles where a similar project was conducted and reported the activity in Mauritius through discussions with related people. Those activities will contribute to enhancing the engineering capacity in Mauritius.

Chapter 1

Introduction

1 Introduction

1.1 General

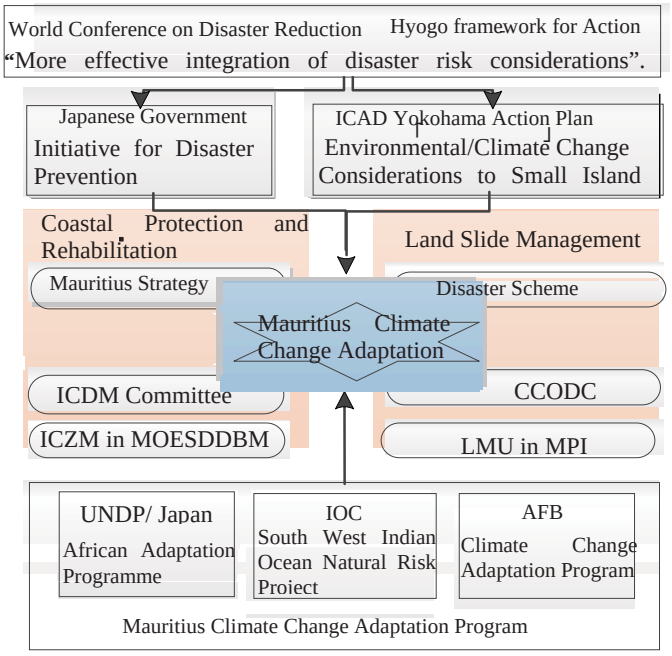
The Project for Capacity Development on Coastal Protection and Rehabilitation in the Republic of Mauritius (hereinafter referred to as 'the Project') started according to the Minutes of Meeting (hereinafter referred to as 'M/M') agreed upon between the Ministry of Environment, Sustainable Development, Disaster and Beach Management (hereinafter referred to as 'MOESDDBM') of the Republic of Mauritius (hereinafter referred to as 'Mauritius') and the Japan International Cooperation Agency (hereinafter referred to as 'JICA').

JICA dispatched 16 experts (hereinafter referred to as 'JET', or 'JICA Expert Team') specializing in investigation, analysis, design and coastal erosion counter measures. The Project was conducted with the MOESDDBM members as Counterparts (hereinafter referred to as the 'C/P') from May 2012 to June 2015.

This report is a Final Report (hereinafter referred to as 'FR') which covers the results of the basic study, the formulation of the coastal conservation plan, the results of demonstration projects and technology transfer.

1.2 Background of the Project

In the Hyogo Framework for Action (hereinafter referred to as 'HFA') adopted by the World Conference on Disaster Reduction (hereinafter referred to as 'WCDR'), signatory countries agreed on a disaster prevention action plan for 10 years under this framework, establishing more effective integration of disaster risk considerations with a special emphasis on disaster prevention as a strategic goal. Based on this framework, the Japanese Government announced the Initiative for Disaster Reduction through Official Development Assistance (hereinafter referred to as 'ODA'), and the Yokohama Action Plan compiled at the Fourth Tokyo International Conference on African Development (hereinafter referred to as 'TICAD IV') which addressed environmental/climate change issues as an urgent challenge. In the Summary by the Chair of TICAD IV, Japan mentioned special considerations to small island developing states. (Refer to Figure 1.2.1)



Source: JICA Expert Team

Figure 1.2.1 Efforts to the Climate Change Adaptation by Mauritius, Japan and World

The government of Mauritius (GOM) responded by establishing the National Climate Change Committee in 1990 to mitigate the impacts of climate change. In 1998 it established a Climate Change Action Plan in accordance with the United Nations Framework Convention on Climate

Change. The Plan made climate change adaptation measures—coastal protection measures such as seawalls and coral protection—a strategy of national importance. In 2000, the ICZM division was established and provisions were made in the EPA 2002 for the ICZM Committee.

Mauritius is vulnerable to climate change, particularly to coastal erosion issues which are becoming more serious due to natural disasters. In addition, anthropogenic activities are exacerbating the degradation of coral reef ecosystems. The country has come up with plans and measures based on scientific and technical grounds. However, consultancy services from international firms are hired since the local counterparts do not have all the necessary skills to meet their objectives. So far, Mauritius has been undertaking disaster prevention measures since the 1990's as shown in Table 1.2.1. In this context, the Government of Japan has agreed to provide technical assistance on coastal protection and rehabilitation to the Government of Mauritius following requests to do so by the latter.

Table 1.2.1 Overview of Coastal Protection / Rehabilitation in Mauritius

Year	Coastal Protection/Rehabilitation
1990	Establishment of National Climate Committee (NCC)
1998	Formulation of Climate Change Action Plan (NCC)
2000	Establishment of ICZM Division in the MOESDDBM
2002	Establishment of Integrated Coastal Zone Management Committee (ICZM Committee) Beginning of the study on coastal erosion in the Republic of Mauritius (Baird, 2003) to understand the present status of coastal erosion and to plan the coastal protection measures
2003	Implementation of the study on coastal erosion by the ICZM division of the MOESDDBM
2005	Mauritius strategy for the further implementation of the programme of action for the sustainable development of small island developing states
2010	Preparation of report on Mauritius strategy for national assessment ICZM Framework study Study on Environmentally Sensitive Areas

Source: JICA Expert Team

1.3 Objectives of the Project

1.3.1 Goal

The goal of the Project is to prepare the "Coastal Conservation Plan" which will be implemented by the Government of Mauritius.

1.3.2 Project Purpose

The purpose of the project is to:

(i) identify the sites affected by coastal erosion,

(ii) formulate a coastal conservation plan,

(iii) select the priority coasts which are necessary for preventive measures based on the plan,

(iv) conduct a detailed study, demonstration projects and continuous monitoring,

(v) develop the capacity of governmental agencies in coastal protection and rehabilitation.

1.3.3 Outcomes of the Project

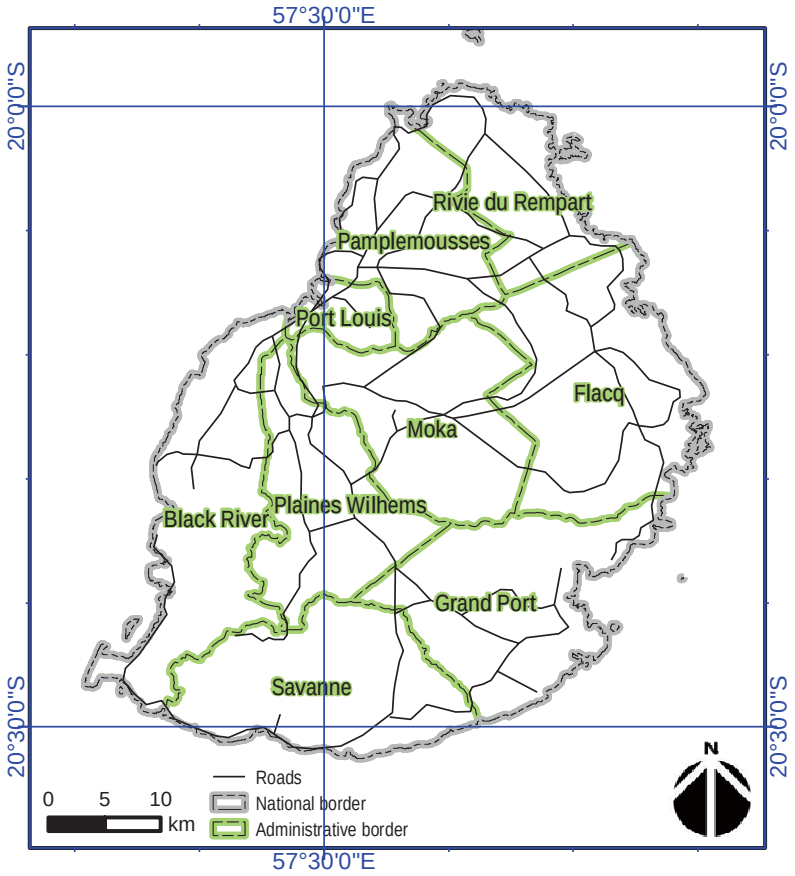
Expected outcomes of the Project are;

1) The affected sites are identified through baseline survey.
2) The coastal conservation plans in the main island of Mauritius are formulated.
3) The effectiveness of the coastal conservation plans is validated through demonstration projects.
4) The technical capacity of the staff in the MOESDDBM and other organizations is enhanced.

1.4 Study Components and Methods

1.4.1 Project Areas

The project area is the Mauritius Island as shown in Figure 1.4.1



Source: JICA Expert Team

Figure 1.4.1 Map of the Project Area

1.4.2 List of JICA Expert Team and Counterparts

The Counterpart (C/P) of the Project is the Ministry of Environment, Sustainable Development, Disaster and Beach Management (MOESDDBM) and the C/P members are composed of the Integrated Coastal Zone Management (ICZM) Division in the Department of Environment in the MOESDDBM.

The names of the JICA Expert Team (hereinafter referred to as JET) members and counterparts are listed below. Table 1.4.1 indicates the role of each member.

Table 1.4.1 List of JICA Expert Team and Counterparts

	JICA Experts	Field of Expertise	Counterpart (MOESDDBM)
1	Mr. Kensuke ICHIKAWA	Chief adviser	Mr. Rajiv BEEDASSY Mr. Ramchurn SEENAUTH Mr. Luqman MAGHO Mrs. S R Nashreen Banu SOOGUN Mr. Amit JHEENGUT Ms. Henna RAMDOUR Mrs. Indramatee AULIAR Mrs. Sandhya JOWAHIR Ms. Sivajyodee Sannassy PILLY Mr. Anand DHOOMUN
2	Dr. Hiroshi HASHIMOTO	Vice chief adviser /Coastal conservation plan	
3	Mr. Susumu ONAKA	Countermeasure to Coastal Erosion/Monitoring	
4	Mr. Minoru ITSUI	Coastal Transformation Analysis	
5	Mr. Shubun ENDO	Coastal Space Management	
6	Mr. Masaki WASHIDA	Design-1 (Basic Design)	
7	Mr. Tomomi FUJITA	Design-2 (Detailed Design) /Cost Estimation	
8	Mr. Masahiro SHIRATORI	Supervision	
9	Mr. Shingo ICHIKAWA	Participatory Coastal Management/IEC Plan	
10	Mr. Masaaki SAKURABA	Natural Condition Survey/ Analysis	
11	Dr. Satoshi NOJIMA	Coral Reef Conservation	
12	Mr. Hiroyuki TAKAKAZE	Economic, Financial Analysis	
13	Ms. Kiyomi SAITO/ Mr. Shingo ICHIKAWA	Institution/System analysis/Capacity development	
14	Mr. Masami SUGITA	GIS/Topographic survey	
15	Mr. Takayoshi KURATA	Water quality management/Environmental and social consideration	
16	Ms. Haruka YOSHIDA	Coordinator	
17	Ms. Shalina MUNGROO Mr. Nissar SUMODHEE	Project Assistant	

Source: JICA Expert Team

1.5 Major Activities and Schedule

1.5.1 Major Activities

The Project was divided into four components namely; Component 1 “Basic study”, Component 2 “Formulation of Coastal Conservation Plan”, Component 3 “Implementation of demonstration projects” and Component 4 “Technical transfer”.

The basic study was conducted to understand the conditions and problems in the coastal zone. Information was collected in relation to the policy for the integrated coastal zone management, organization, natural and socioeconomic conditions, and past coastal disasters. Those activities are as follows :

1) Collection and analysis of existing materials and data
2) Interpretation of geographical features, water quality and bottom material monitoring
3) Data analysis
4) Identification of existing conditions and risks
5) Identification of areas affected by erosion and degradation of coral reef ecosystems
6) Database building on coastal environment

The coastal conservation plan was formulated based on the problems in the coastal zone and comprised the following activities:

1) Formulating a coastal conservation strategy
2) Preparing a coastal conservation and rehabilitation plan
3) Drafting a coastal space management plan
4) Preparing a coral reef conservation plan
5) Formulating a coastal management system and organization plan
6) Preparing an Information, Education and Communication plan (IEC plan)
7) Selecting a demonstration project
8) Comprehensively evaluating the coastal conservation plan

The components of the demonstration project included implementing coastal conservation measures, continuous monitoring to evaluate the conservation plan, obtaining feedback on the effectiveness of measures implemented. With regard to capacity, the following was incorporated:

1) Implementing detailed surveys
2) Preparing physical measure plans
3) Implementing physical measures
4) Preparing non-physical measure plan
5) Implementing non-physical measures
6) Monitoring and evaluation demonstration project
7) Making proposals on continuous monitoring and countermeasures

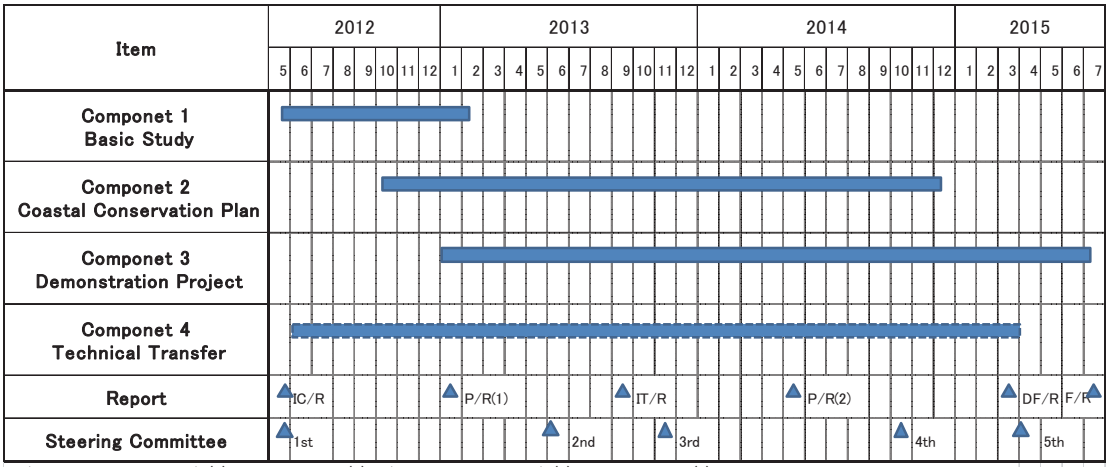
The coastal management technical transfer is intended to enhance the capacity of related governmental organizations follows:

1) Preparing technical guidelines on coastal conservation
2) Drafting monitoring guidelines

3) Preparing EIA guidelines specific to the coastal conservation project
4) Participating in Workshops, seminars, training in Japan and technology exchange

1.5.2 Work Schedule

The work schedule of each component is shown in Figure 1.5.1.



Source: JICA Expert Team

Figure 1.5.1 Flowchart of the Project Activities

Chapter 2

Basic Study

2 Basic Study

2.1 Summary

The object of the Project is to conserve the coast of Mauritius in an appropriate manner. The purposes are to identify the affected sites of coastal erosion, to formulate a coastal conservation plan, and to select the priority coasts which are necessary for preventive measures based on the plan and to conduct a detailed study, demonstration projects and continuous monitoring. The capacity of governmental agencies is expected to be strengthened through working cooperatively on the abovementioned activities.

The basic study was conducted to understand the relevant natural conditions, socioeconomic conditions, policies, laws and organizations, and to analyze the coastal erosion and coastal disasters. The conditions of coral and water quality were also surveyed. From the results the affected coast and issue were identified. The results of the basic study were compiled as a coastal environment database. The summary is shown in Table 2.1.1 and further details are outlined thereafter.

Table 2.1.1 Outline of Basic Study Results

Chapter No.	Outline
2.2 Natural Conditions	(1) Geography and Geology ➢ Geography: The coastline of Mauritius is 322km long and coral reefs are 150km long. Total area is 243km^2. The coast is formed by sandy beaches, gravel beaches, mud flats, wetlands, rocky cliffs and mixtures of these. ➢ Geology: The coast at the northeast was formed by lava of over 20 thousand years ago and at the others by lava of over 100 thousand years ago. (2) Coastal Topography ➢ Coast: The reefs are 100m to 1km wide along the northern and western coasts, and over 5km wide along the eastern coast. The coast in Mauritius is classified into four types: type A) sandy beaches with a narrow reef, type B) wide reef, type C) cliff coast without a reef, and type D) silt, mud and cobble coast with a wide reef. Refer to section 2.2.2 for further details. ➢ Bed material: The grain size (D50) of main coasts is 0.2-0.34mm at Mon Choisy, Flic en Flac and Pte. d'Esny, 0.5-0.8mm at Le Morne, 0.4-1.4mm at Pte. aux Piment. The grain size outside of the reef is over 0.5mm at Trou aux Biches and Le Morne. It was confirmed that they are available for sand nourishment. (3) Climate ➢ Climate and rainfall: Mauritius belongs to a tropical climate. There is no division of the dry season and the rainy season. Two thirds of the annual rainfall from December to May. ➢ Wind : Wind of ENE to SSE dominates from November to February and SSE from May to August ➢ Cyclone: Cyclones mostly make landfall from December to March. The severe cyclones were Alix and Carol in 1960, Gervaise in 1975, Hollanda in 1994 and Dina in 2002. ➢ Sea conditions: Tide is semidiurnal. Mean tidal level is high from January to March and low from May to October. The mean sea level rises 3.9mm/year at Port Louis in the past 30 years. Mean significant waves are 1.5 to 2.5m high from SSW to ESE in

Chapter No.	Outline
	summer and 2.5 to 3.5m in winter. The waves in a reef are about 0.3m high and the ratio of wave height to water depth is from 0.07 to 0.09. The current in a reef at Pointe d'Esny is under 10cm/s.
2.3 Socio-economic Conditions, Finance, Policies, Laws and Organizations	➢ Socio-economic Conditions: Growth rate of GDP is 6%, the manufacture sector accounts for 16% of the total, and the tourism industry is 6%. ➢ Tourism: Growth rate of tourists is about 4% with 1.04 million tourists per year (2014). The number of hotels registered in Mauritius was 112. There are 52 large hotels with more than 80 rooms, which account for 75% of total beds in Mauritius. ➢ Finance: Budget of MOESDDBM is Rs 570 million in 2013 and allocated Rs 200 million for environment conservation and protection. Increase in staff budget is expected from 2014 to 2016. ➢ Economy: Tourism revenue in 2013 accounts for 12% of GDP and Rs 40.5 billion. The percentage is increasing year by year. The land use of the coastal zone is 23% for agriculture, then bungalows and hotels. (1) Policies, Laws and Organizations ➢ National policies: National objectives of integrated coastal zone management are indicated in the National Development Strategy and Environmental Policy. ➢ Laws: definition of coastal zone, land ownership, classification of coastal zone, setback regulation, building code and environmental impact assessment are defined. ➢ Organizations: Ministries mainly related to ICZM are 6 among 25 ministries. The role is defined in detail according to the basic study, conservation plan, design and implementation, coastal management and monitoring.
2.4 Past Coastal Disaster and Measures	➢ Coastal disaster: Past cyclones Carol (1960), Hollanda (1994), and Dina (2002) caused severe damages. ➢ Coastal structures: Transition of structures was small structures from 1960 to 1993, gabions from 1994 to 2003, and rock revetments from 2003 to 2013.
2.5 Analysis of Coastline	➢ Erosion analysis from aerial photos: Aerial photos were used in 1967, 1975, 1991, 1997 and 1999. Satellite images in 2008 and 2012 were also used. ➢ Method: Digitizing the coastline using aerial photos by GIS. ➢ Result: Long term erosion was 17%, stable coast 59%, and accreted one 23%. Eighteen coasts show erosion of 0.2m/year and the short term change are 0.5m/year on average. ➢ Discussion: Short term change is larger than the long term erosion and the effect of topographic change due to cyclone is remarkable.
2.6 Reef Environment	(1) Water quality ➢ Monitoring: The water quality is monitored by AFRC in lagoon, NEL for rivers and lakes, WMA for sewerage, CWA for drinking water. Water pollution is significant in the lagoon at Pointe aux Sable、Albion、Baird Sanctuary, Riviere Noire after 2007. At Pointe aux Sable coliform concentration is significantly higher.

Chapter No.	Outline
	➢ Water quality: The water quality was measured at eight coasts where the beach is sand beach with reef and expected tourism development. The results show that the coverage of live coral decreases according to the increase of siltation, chlorophyll a, nitrogen and phosphorus in lagoon. The contribution of the pollution load from hinterland, rivers and wetland is high. Measures to reduce the inflow and to prevent eutrophication are important in reef environmental protection. (2) Coral reef ➢ Coral monitoring: Coral was monitored at 50 sites by spot check method. The results show that the coverage of live coral is 27% on average of 44 points and lower than the reference. The relation between coral coverage and transparency is positive and sedimentation of silt is negative. The average coverage of 19% in 2010 decreased from 51% in 2000 significantly. ➢ Problems: The main problems in a reef are the degradation of coral, the decrease of juvenile coral, sharp decline of table coral that was once occupied, regional disappearance of several species, coral bleaching in 2003, 2004 and 2009, eutrophication, abnormal increase of micro algae in summer, deposition of silt, decrease of transparency, and large nets fishing.
2.7 Public Awareness	➢ The main contents of questionnaire: (1) Damages of coastal areas by the cyclone in the past, (2) Long term trend of coastal erosion, (3) Awareness of coastal disasters associated with the climate change in future (4) Desirable countermeasures against coastal disasters due to climate change, (5) Desirable facilities and willingness to pay for coastal conservation ➢ Result: (1) & (2) There has been no reports of large scale erosion, (3) About 25% of people show willingness to pay for conservation measures, (4) High awareness of environmental issues as well as coastal protection, (5) 50% of respondents were in favor of conservation measures by hard structures and 30% by beach nourishment
2.8 Coastal Environment Data Base	➢ Existing database: Administrative district, infrastructure, geological map, soil map, land use map, mangrove map, contour line, observation point, nature reservation map, and public beach. The coordinate system of the data was unified as WGS84, UTM zone 40S since a few different coordinates were applied for the existing database. ➢ New GIS data: Digitized coastline data of 13 target coasts from the aerial photo in 1967, 1975, 1991, from 1997 to 2000 and the satellite image in 2008 and from 2011 to 2012. From the data the sediment budget was analysed.

Source: JICA Expert Team

2.2 Natural Conditions

2.2.1 Geographic and Geological Conditions

a. Geography

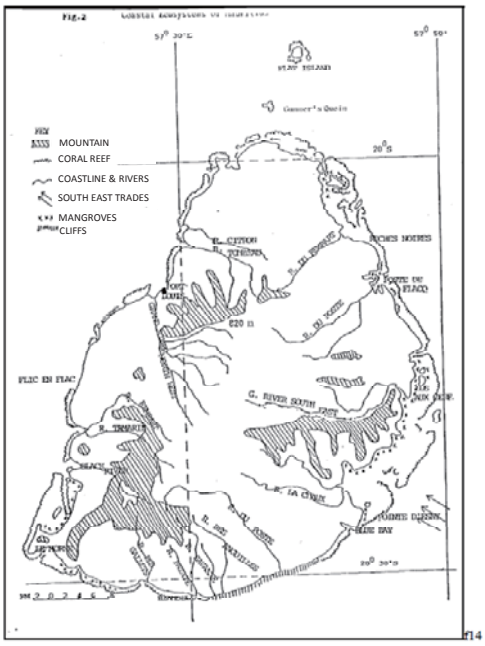
Mauritius is a volcanic island in the Indian Ocean, which is located approximately 800 km to the east of Madagascar. The area of the island is about 1860km^2 with 60km length in the

north-south direction and 50km length in the east-west direction. The island has a mountainous topography and the highest peak of elevation is 817m. Fifty rivers flow into the lagoons around Mauritius. The total stretch of the coastline including surround isolated islands is about 496km. There is no continental shelf, where the water depth is more than 3000m, within 20 km offshore of Mauritius.

The stretch of coastline for Mauritius Island itself is 322 km, the area of lagoon is 243 km^2, and the length of reef is about 150 km. The mangrove forests exist around the river mouth with 14 km^2 in total. The geography of the coastal area in Mauritius has several variations, such as sand, boulder, gravel, silt, limestone, etc. as shown in Figure 2.2.1.

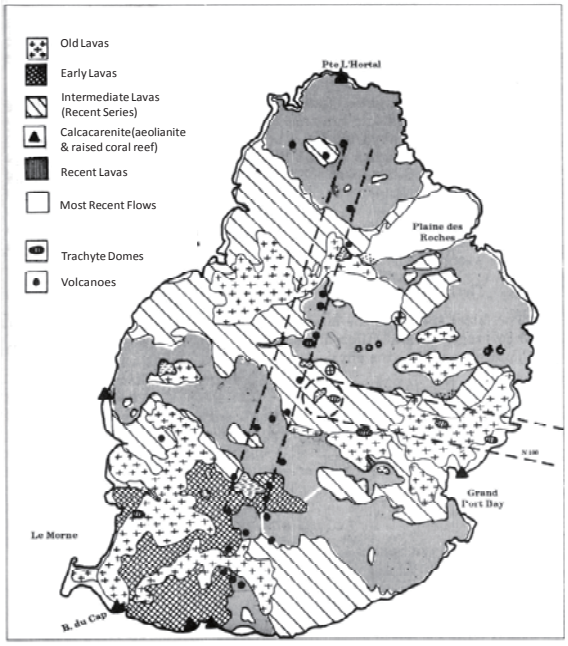
b. Geology

Figure 2.2.1 shows the geological map of Mauritius Island. From 10 million to 6 million-years before, it was a volcanic activity period in Mauritius Island. The geology at southwest coast consists of the lava which was formed over 7 million years ago. The geology at northeast coast consists of the lava which was formed over 20 thousand years ago. The geology at other areas consists of the lava of over 10 thousand years ago.



Coastal Geography

Source : IOC-UNEP-WMO-SAREC, Planning Workshop on An Integrated Approach to Coastal Erosion, Sea Level Changes and Their Impacts



Geology

Source : Mauritius A Geomorphological Analysis

Figure 2.2.1 Coastal Geography and Geology of Mauritius Island

2.2.2 Beach Geography

a. Beach Type & Geography

Figure 2.2.2 shows the typical coastal geography in Mauritius. Mauritius is a volcanic island formed by upheaval of the submarine volcano. However most of coasts are formed by coral

sediment. The photos at north and west coast shown in Figure 2.2.2 is the coasts with such characteristics. Here, the width of the coral reef is from 100m to less than 1km. On the other hand, east coast has wide coral reef compared to north and west coasts and there are some coasts where the width of coral reef is more than 5km. The coast with such conditions is formed by silty sand, clay humus soil and gravel. South coast is mainly formed by rocky cliff except some area of southwest coast. The coast formed by gravel also exists at south area. The main source of the sedimentation coral sand is coral and coral rock which were breaking at the reef edge due to breaking wave action.

North: Pte. aux Cannoniers

South：Reviere des Galets

West：Flic en Flac

East: Grand Sable

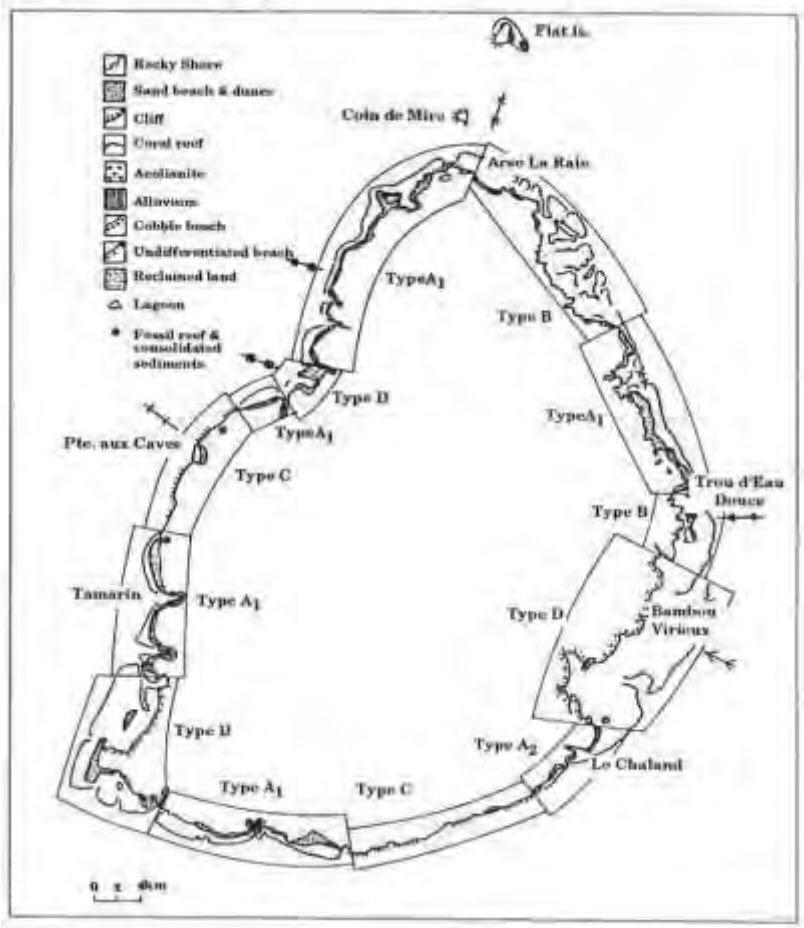
Source: JICA Expert Team

Figure 2.2.2 Typical Geography of Public Beach

The coasts are classified according to the characteristics to analyze the coastline changes and their countermeasures. Twenty coasts were selected for the basic study. The coastline was finally classified based on the geology and the topography of the coastal zone by Saddul (Saddul, Prem: Mauritius, A Geographical Analysis, Mahatma Gandhi Institute, 2002, rev.) It said the coastline can be classified into the following four groups:

Type A: Sandy coast with a narrow reef (including Type A1 & Type A2)
Type B: Coast with a wide reef
Type C: Cliff coast without a reef
Type D: Silt, mud and cobble coast with a wide reef

The distribution of those types is shown in Figure 2.2.3 .Based on the classification, natural conditions, socioeconomic conditions, erosion problems and example coasts are listed in Table 2.2.1.



Source: Saddul, P.: Mauritius, A Geomorphological Analysis, Mahatma Gandhi Institute, rev. 2002

Figure 2.2.3 Coastal Classification of Mauritius Island

Table 2.2.1 Coastal Classification and its Characteristics

Item	Explanation
Classification	Type A: The Recent Series coastline with a narrow reef
Natural Condition	The beach is covered by coral sand which is produced by wave action and transported onshore on the reef found within 1 km. The coastal current generated by breaking waves contributes to onshore and longshore sediment transport.
Socioeconomic Condition	Because the sandy beach is important resources, tourism activities has been developed such as bathing and boating with the development of hotels, bungalows, restaurants and souvenir shops at the north, northwest and west coast. At the south the beach keeps its natural conditions but future development is expected.
Erosion Problem	Basically beach sand has been supplied from the reef and in total the beach sand is increasing. However seasonal variation of waves causes erosion at one place and accretion at the other place. Sometimes cyclones cause offshore sediment movement, namely beach erosion. Coastal structures and sand mining also cause erosion problems.
Example	Baie de Tombeau to Cap Malheureux, Points Roches Noires to Trou d'Eau Douce, Pte. d'Esny to Ilot Brocus, Petite Riviere Noire Bay to Flic en Flac, Pointe aux Sables

Item	Explanation
Classification	Type B: recent series coastline with a wide reef
Natural Conditions	The coast is characterized by the general absence of a beach. Deposits of rounded cobbles of basalt are often noticed while sandy beaches occur in some rare places such as Poudre d'Or. The reef lies at a distance of 2-5 km from the coast.
Socioeconomic Conditions	Have hotels and bungalows.
Erosion Problems	Basically erosion is rare because the movement of beach material is not active.
Examples	Cap Malheureux to Roches Noires, GRSE to Trou d'Eau Douce

Item	Explanation
Classification	Type C: recent series coastline without a coral reef (cliff)
Natural Conditions	The coast was formed as cliff associate with a wave-cut platform without a coral reef. Usually cliffs are about 30 m high.
Socioeconomic Conditions	Mostly on the landward of the cliff sugar cane fields are expanding. In some area housing developments are active.
Erosion Problems	The cliff has been eroded by wave action together with seepage of ground water. But the changing is slow compared to sandy coast.
Examples	Le Soufleur to Souillac, North and south of Albion Bay

Item	Explanation
Classification	Type D: old series coastline with a wide reef
Natural Conditions	A wide shelf more than 5 km in extension and accumulated with sediment material from landward and pushes coral reef further away. There are no sand beaches along coast. The load of calcareous sediment accumulates in the deep channel separating it from the shore and obstructing it from reaching the coast.
Socioeconomic Conditions	Coastal road runs along the coast.
Erosion Problems	Basically there are no erosion problems. However a road runs along the coast and this is thought to be susceptible to future wave overtopping problems because of low ground height.
Examples	GRSE to Mahebourg, Baie du Cap to Petite Riviere Noire Bay, GRNW to Riviere Terre Rouge

Source: JICA Expert Team

b. Relation between Beach Slope and of Grain Size

The coastal area in Mauritius is classified about the geographical feature and the geology of the coast according to each area. However, the relation between the coastal geography and the seabed material has not been investigated. In this study, the seabed material survey has been carried out in several coasts. And the relation between the characteristic of coast and the seabed material has been investigated. The purposes of this study are as follows:

- Investigating the relation between the grain size on the coast and the beach slope in order to obtain the basic information which will be utilized in the planning of beach nourishment (beach profiling).
- Investigating the difference of seabed material especially the difference of grain size in on-offshore direction in order to know the characteristics of sand transport on the reef.

- Investigating the characteristics of seabed materials at outer reef nearby the reef gap in order to verify the possibility of sand mining to be utilized for the future beach nourishment (beach profiling).

The survey item, purpose and objective coast for each survey are summarized in Table 2.2.2.

Table 2.2.2 Survey Item and Purpose

Survey Item	Purpose of survey	Sampling Site
Item1 : Beach slope survey and seabed material sampling	Obtaining the basic information about the beach slope. Investigating the relation between the seabed material and the beach slope. Surveying the longitudinal section easily.	Mon Choisy Pte. aux Piments Flic en Flac Le Morne Pte. d'Esny
Item2 : Seabed material sampling in lagoon	Sampling the seabed material from the reef edge to shoreline on the reef and analyzing the grain size. Obtaining the relation between reef width, position of reef edge and grain size of coral sand.	Grand Sable Le Morne Albion
Item3 : Seabed material sampling in reef gap	Obtaining the basic information of seabed material as potential borrow sites for sand nourishment.	Grand Sable Flic en Flac Trou aux Biches Le Morne Albion

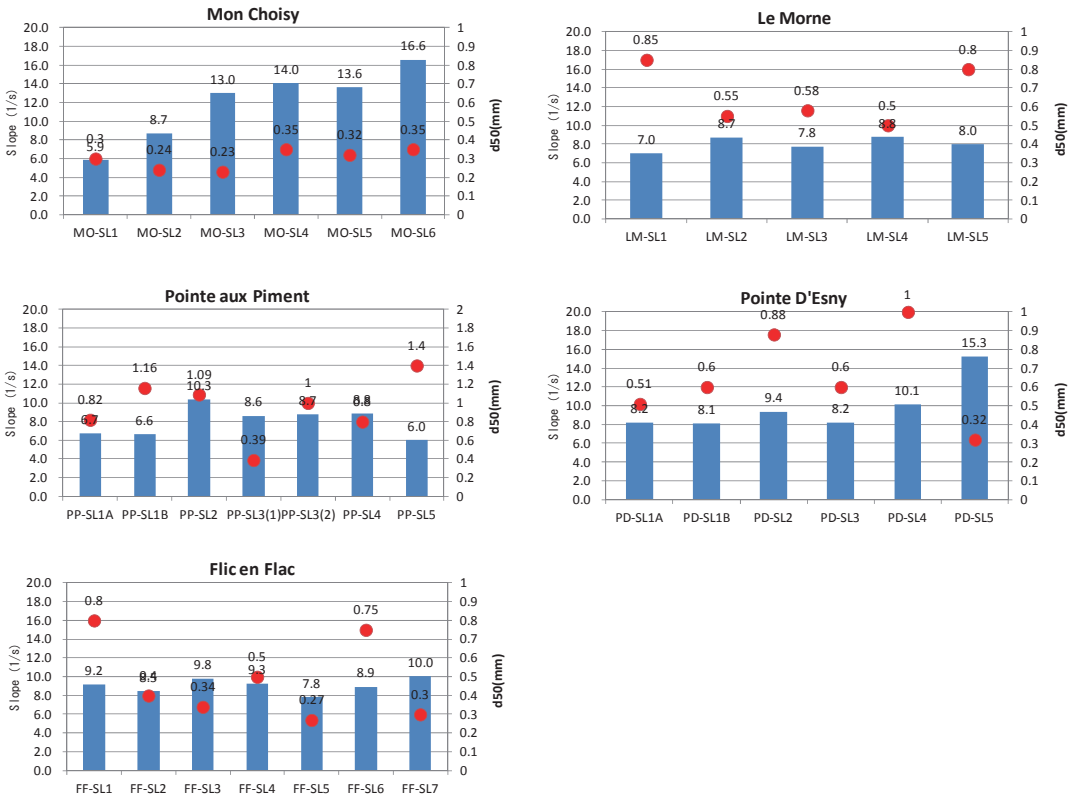
Source: JICA Expert Team

Particular features on Beach Slope (Figure 2.2.4)

- The beach slope at the north part of Mon Choisy is smaller than that at the south part. This result indicates that the fine sand might be transported from south to north due to northward littoral drift.
- There is no significant difference of beach slope between Pte. aux Pimente and Le Morne, and the beach slope is about 1/7. The beach slope at Flic en Flac is about 1/10, which was smaller than that at other coasts.
- The beach slope at the north part of Pte. d'Esny is smaller than that at the south part. Even though the tendency for the change in beach slope at Pte. d'Esny is smaller than that for Mon Choisy, this is indicating that the components of fine sand are transported from south to north.

Particular features on Grain Size (Figure 2.2.4)

- The grain size of sand at Mon Choisy, Flic en Flac and Pte. d'Esny is distributed 0.2 to 0.34mm. These results indicate that the grain size at these coasts is smaller than other coasts in Mauritius.
- The grain size at the inner reef area of Le Morne is 0.5 to 0.8 mm. The grain size at the outer reef area is 0.75 mm.
- The grain size at Pte. aux Piment is distributed from 0.4 to 0.8mm. The tendency for the difference of grain size due to littoral drift is not observed.

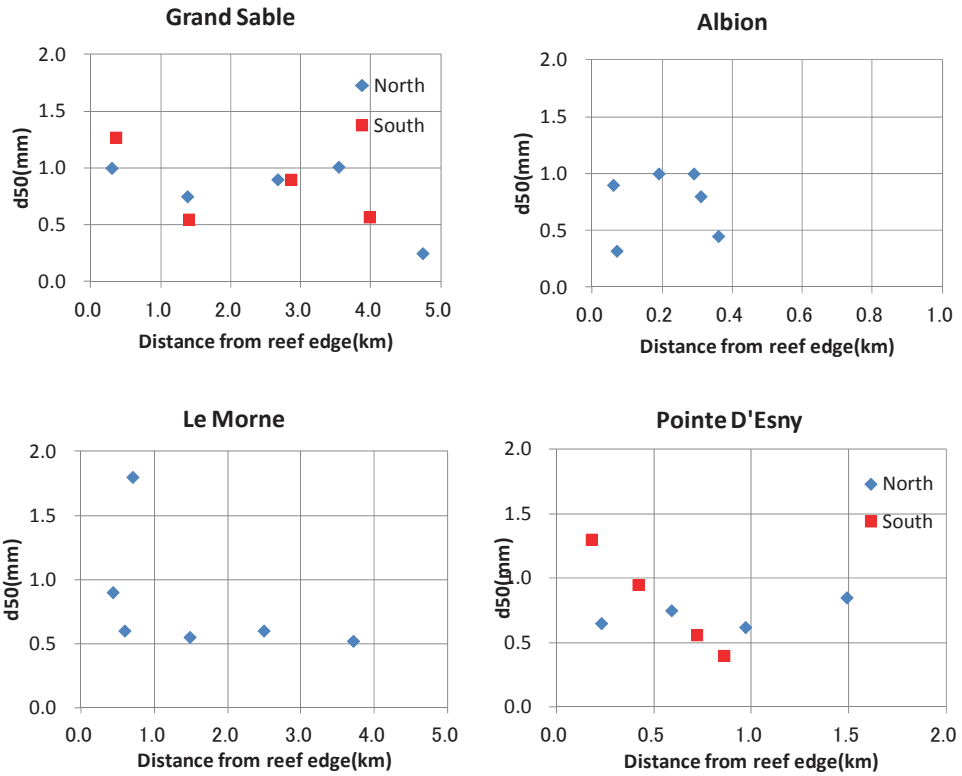


Source: JICA Expert Team

Figure 2.2.4 Relation between Beach Slope and Grain Size

Figure 2.2.5 shows the relationship between the distance from the reef edge and the grain size.

- The width of the coral reef at Grand Sable is about 5km. The grain size becomes smaller in accordance with the distance from reef edge at both north and south points. This trend indicates that the coarse sand is transported from onshore to offshore after been broken off of the reef edge. The grain size becomes large at the point of 4km from the reef edge. The existence of natural channel might be influenced by such changes of grain size.
- The width of the coral reef at Pte. d'Esny drastically changes from 0.5km at the south part to 2km at the north. The grain size at the south area changes from 1.3mm nearby the reef edge to almost half at the middle point. On the other hand, there is no significant on-offshore difference of grain size at the north part. This difference of tendency for the distribution of the grain size between the south and the north part might be caused by the difference of the width of the coral reef.
- No tendency for the difference of grain size at on-offshore direction was observed at Le Morne and Albion.

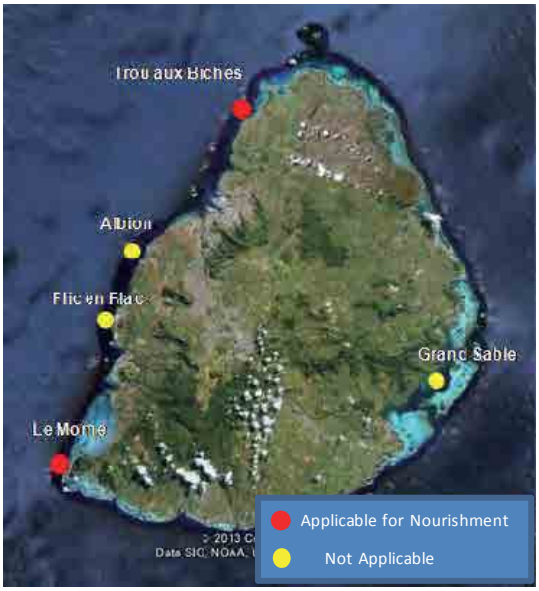


Source: JICA Expert Team

Figure 2.2.5 Relation between Distance of Reef Edge and Grain Size

Characteristics of Grain Size at Outer Reef:

The survey results at outer reef gives the suitable sites at Trou aux Biches and Le Morne where the grain size is over 0.3mm which can be used for nourishment as shown in Figure 2.2.6. Others are under 0.3mm or difficult to take sand samples.



Source: Arranged by JICA Expert Team based on Google map.

Figure 2.2.6 Potential Sand Extraction Sites for Nourishment

2.2.3 Characteristics of Meteorology

Mauritius is influenced by the south-east trade winds, and belongs to the subtropical climate. There are two seasons. One is the summer season (rainy season) from November to April with the average temperature of 24.7°C, and another is the winter season (dry season) is from June to September with the average temperature of 20.4°C. Temperature variation between both seasons is 4.3°C only. The warmest months are January and February with daily max. temperature of 29.2°C on average, while the coldest months are July and August with daily min. temperature at night time of 16.4°C.

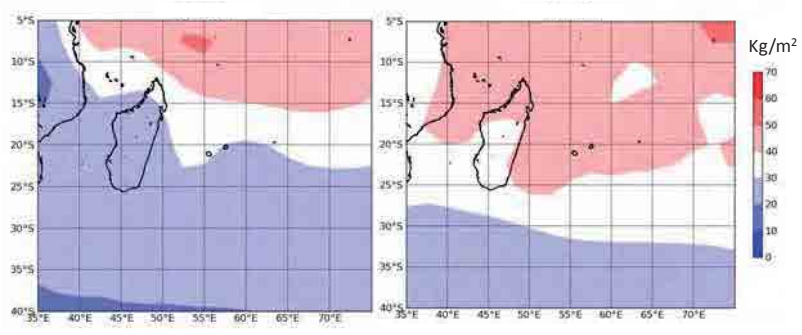
Annual precipitation ranges between 900mm at coastal areas and 1,500mm at central highland. The most of rain is concentrated during several months of summer season. Seawater temperature in lagoon areas ranges from 22°C to 27°C. Temperature at central highland is rather lower than that of coastal areas, while precipitation at central highlands becomes twice that of coastal areas.

Due to the south-east trade winds caused by high pressure in those areas, the weather in the eastern part of the island is rainy and lower temperature. Weather conditions in both sides of the island may be remarkably different. Tropical cyclones in Mauritius commonly occurs during January to March. They bring heavy rain and strong winds for about 3 days.

a. Meteorology & Rainfall

Mauritius is located near the 20th parallel south latitude in the South Indian Ocean and has a subtropical climate. Most rainfall is recorded from November to April, while it decreases after this period. In order to confirm this tendency, the distribution of potential precipitation (i.e. the total amount of precipitation if all the steams in the unit air column were to precipitate) has been studied. Figure 2.2.7 shows the said distribution at the vicinity of Mauritius (35 degrees on every side) in June and December (average value in 1980~2000 reviewed by NCEP: National Centers for Environmental Prediction/NCAR: National Center for Atmospheric Research). As a result, it shows that monthly potential precipitation in June is around 30kg/m^2,while that in December is 40~50kg/ m^2. It means that December probably has more rain than June.

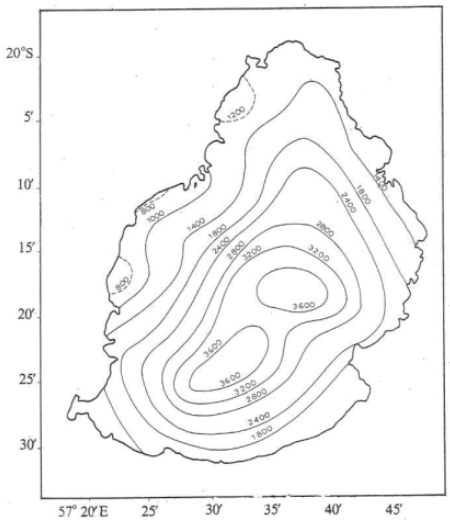
Monthly average precipitation in Mauritius is shown in Figure 2.2.8 (average value in 1951-1980). Remarkable differences are not found between dry season and rainy season, but 2/3 of annual precipitation is recorded in December to May. October has least rain in the year, on the other hand, March has the most. The annual rainfall in hilly areas is more than three times that of coastal areas.



Source: Arranged by JICA Expert Team based on NCEP/NCAR Re-analysis Result

Figure 2.2.7 Monthly average precipitation (1979-2013)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
mm	295	280	309	216	161	140	133	124	83	74	101	206	2122
% of annual	13.9	12.2	14.5	10.2	7.6	6.6	6.3	5.7	3.9	3.5	4.7	9.7	100



Source: Weather and Climate in Mauritius

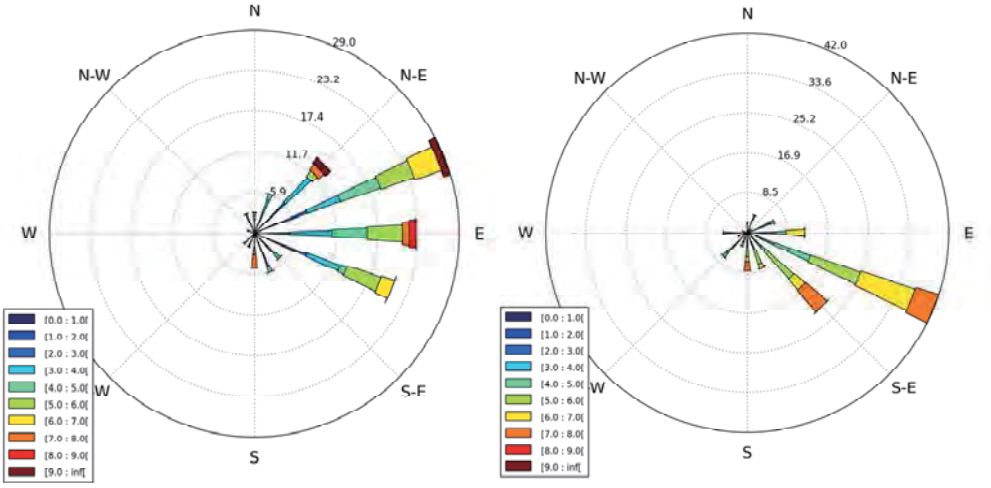
Figure 2.2.8 Variation and Distribution of Monthly Average Precipitation

b. Wind Conditions

Tropical cyclones in Mauritius occur frequently in the summer season, while the south-east trade winds exert a strong influence in the winter season. Figure 2.2.9 shows the wind rose including velocity and direction at Plaisance observation station in 2013. Wind of ENE-ESE is predominated in summer (November to February). Particularly, the wind blowing from ENE has a large velocity which seems to be caused by cyclones. While, the wind of ESE is predominant in winter (May to August). It is caused by the south-east trade winds in the whole of the South Indian Ocean. Wind velocity is rather larger in winter season. Also, Figure 2.2.10 shows the monthly average of wind velocity in January and July (1980-2000), and Figure 2.2.11 shows the sample of wind direction in same months in 2002 as well.

As a result, wind velocity of winter season is more than 10m/s on average, while that of summer season is 5-6m/s. Wind direction is strongly influenced by the south-east trade winds in June, but such winds have little influence in December. Seasonal wind conditions are summarized as follows.

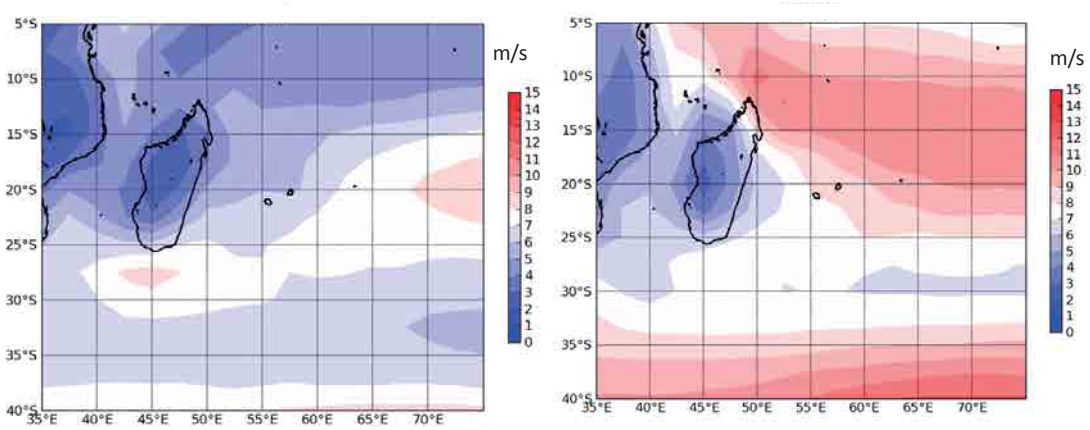
- Wind conditions are strongly influenced by the south-east trade winds in the winter season (i.e. May to August). Since wind of ESE is predominated, wind velocity is bigger in south-eastern part of Mauritius.
- Influence by the south-east trade winds decreases in the summer season (i.e. December to February) and wind velocity is relatively smaller.
- However, tropical cyclones in Mauritius frequently occur in the summer season. When the cyclone comes, wind velocity can drastically increase depending on the course of the cyclone.



Nov.-Feb. May-Aug.

Source: Arranged by JICA Expert Team based on Mauritius Meteorological Service

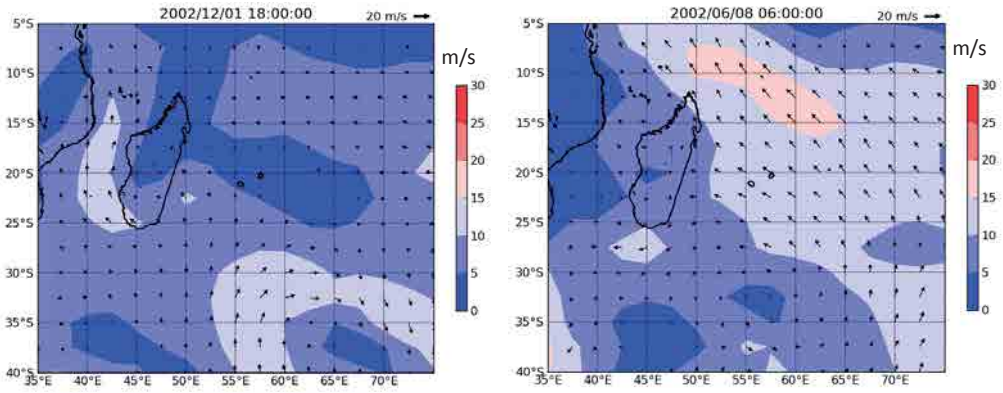
Figure 2.2.9 Wind Velocity/direction (Wind rose) (Plaisance, 2013)



January July

Source: Arranged by JICA Expert Team based on NCEP/NCAR Re-analysis Result

Figure 2.2.10 Average Wind Velocity (1981-2010)



Dec.1, 18:00 Jun.8, 18:00.

Source: Arranged by JICA Expert Team based on NCEP/NCAR Re-analysis Result

Figure 2.2.11 Distribution of Vector of Wind Velocity (2002)

c. Cyclone (Extreme Characteristics and Frequency)

Mauritius is influenced by the south-east trade winds, and belongs to the subtropical climate. The winter season (dry season) is from May to November, and the summer season (rainy season) is from November to May. The tropical cyclone in Mauritius commonly occurs from 30 degree to 60 degrees south latitude in the South Indian Ocean. Mauritius is located at the area where tropical cyclones pass through. And the coastal area has been damaged frequently due to cyclones. Especially, those cyclones frequently affect Mauritius from December to March every year.

The details of past major cyclones, such as date-month, velocity and pressure, are shown in Table 2.2.3. Among them, large scale cyclones, Alix & Carol in 1960, Gervaise in 1975, Hollanda in 1994 and Dina in 2002 have caused serious damage in Mauritius.

Strong winds and low pressure caused by cyclones often generate high waves as well as storm surges. Also, high waves may be the direct external force to produce coastal erosion and other damage in coastal areas. In order to understand the frequency of cyclones, which may produce coastal erosion and other damages, frequency properties of cyclones have been analyzed. Track-map of cyclones was made based on the data which has been downloaded from Southern Hemisphere (1945-2012) of JTWC (i.e. Joint Typhoon Warning Center). Figure 2.2.12 shows the sample of track-map for 10 years since 1995 to 2004. Among those tracks, frequency of cyclone has been analyzed based on the cyclone which have a path within 100km, 300km and 500km of Mauritius.

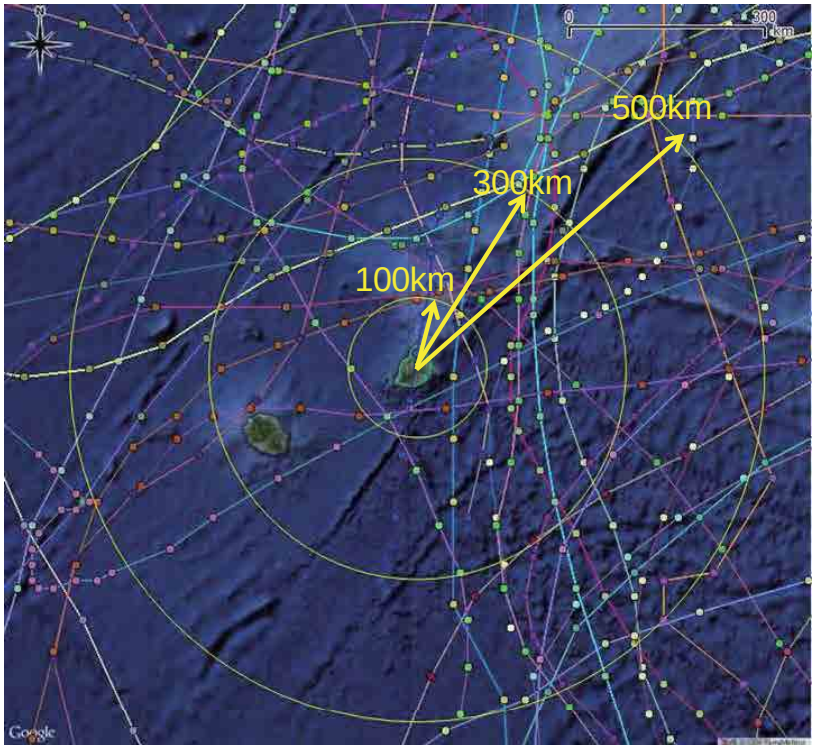
Frequency of cyclones, which occurred within each range of radius since 1945 to 2012, is shown in Figure 2.2.13 hereunder. Also, the locations of the major cyclones are plotted in this Figure 2.2.13. As a result of analysis, it may be judged that the number of cyclones in a year within 500km is 3.3 on average, number of cyclones of within 300km is 1.9 on average and that of within 500km is 0.5. It means that a cyclone occurs once every two years within a 100km radius in Mauritius. Interval of occurrence of major cyclones may be once in approximately 10 to 15 years although it varies greatly. Additionally, no major cyclone has occurred since 2002, so that it is quite possible that a major one will occur in the near future.

Continuously, analysis has been made to know the area where the cyclone would be biggest in the vicinity of Mauritius. Based on the data of cyclones since 1980 for which center pressure is available, the lowest pressure points have been plotted in the vicinity map of Mauritius. Figure 2.2.14 shows those frequencies. The results show that most cyclones become strongest in the northern part of Mauritius. In most cases, cyclones occur in 5-10 degrees south latitude and increase in strength as they move south. Most cyclones reach their greatest force in vicinity of Mauritius. However, the scale and paths of cyclones vary greatly, so the above norms are easily broken. For example, Carol in 1960 and Hollanda in 1994 passed across Mauritius maintaining strong power. Figure 2.2.15 shows two typical tracks and pressure distributions of cyclones that exhibit strong power in northern part of Mauritius. Typically, cyclones becomes stronger in northern Mauritius, however, it could cause high waves in all coastal areas around Mauritius, depending on its wind radius.

Table 2.2.3 Major Cyclones to have Approached Mauritius (largest cyclones are in red)

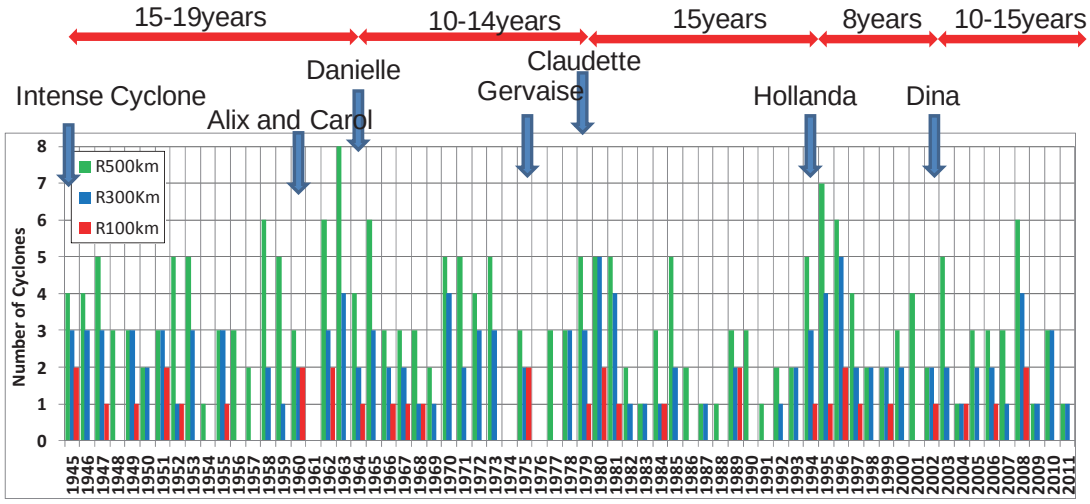
Year	Date-Month	Name	Classification	Nearest Distance from Mauritius	Highest Gusts km/h	Lowest Pressure hPa
1892	29-Apr	-	-	-	216	947
1931	5 – 7 Mar	-	Intense Cyclone	-	180	969
1945	16-17 Jan	-	Intense Cyclone	Over Mauritius	156	953
1945	1-2 Feb	-	Intense Cyclone	South	150	969
1946	30 Jan-1 Feb	-	Intense Cyclone	Close West	129	984
1958	6-9 Apr	-	Intense Cyclone	80 km West Reunion	129	1004
1960	16-20 Jan	Alix	Intense Cyclone	30 km off Port Louis	200	970
1960	25-29 Feb	Carol	Intense Cyclone	Over Mauritius	256	943
1961	22-26 Dec	Beryl	Intense Cyclone	30 km West	171	992
1962	27-28 Feb	Jenny	Intense Cyclone	30 km North	235	995
1964	17-20 Jan	Danielle	Intense Cyclone	40 km South West	219	974
1966	5-7 Jan	Denise	Severe Depression	65 km North West	167	1003
1967	11-14 Jan	Gilberte	Severe Depression	Centre over Eastern	142	978
1970	23-25 Jan	Hermine	Severe Depression	240 km West South	125	999
1970	27-30 Mar	Louise	Intense Cyclone	140 km East	140	988
1972	11-13 Feb	Eugenie	Severe Depression	240 km North North	132	1002
1975	5-7 Feb	Gervaise	Intense Cyclone	Over Mauritius	280	951
1978	18-21 Jan	Fleur	Intense Cyclone	80 km South East	145	986
1979	21-23 Dec	Claudette	Intense Cyclone	Over Mauritius	221	965
1980	24-28 Jan	Hyacinthe	Intense Cyclone	80 km North West	129	993
1980	3-4 Feb	Jacinthe	Intense Cyclone	150 km South East	129	992
1980	12-13 Mar	Laure	Intense Cyclone	30 km North East	201	989
1981	5-7 Jan	Florine	Intense Cyclone	80 km West	135	1003
1982	5-6 Feb	Gabrielle	Mod. Depression	100 km North West	145	1001
1983	23-26 Dec	Bakoly	Intense Cyclone	55 km South West	198	992
1989	27-29 Jan	Firinga	Cyclone	80 km North West	190	994
1989	4-6 Apr	Krissy	Severe Depression	30 km South	150	976
1994	9-11 Feb	Hollanda	Intense Cyclone	20 km North West	216	984
1995	7-8 Jan	Christelle	Mod. Depression	Over Mauritius	109	994
1995	24-27 Feb	Ingrid	Cyclone	100 km North East	153	989
1995	8-13 Mar	Kylie	Severe Depression	135 km West North	114	1005
1996	24-25 Feb	Edwige	Mod. Depression	100 km North	162	1009
1996	14-16 Apr	Itelle	Intense Cyclone	275 km North	109	1011
1996	6-8 Dec	Daniella	Intense Cyclone	40 km South West	170	998
1998	10-11 Feb	Anacelle	Cyclone	50 km East	121	985
1999	8-10 Mar	Davina	Intense Cyclone	25 km South East	173	974
2000	27-29 Jan	Connie	Intense Cyclone	200 km North West	122	1003
2000	13-15 Feb	Eline	Severe Depression	130 km North	129	1006
2002	20-22 Jan	Dina	Very Intense T.C	50 km North	228	988
2003	12-13 Feb	Gerry	Tropical Cyclone	100 km North North	143	990
2003	31 Dec 03-03 Jan 04	Darius	Severe Tropical	40 km South East	113	994
2005	22-24 Mar	Hennie	Severe Tropical	60 km South East	112	990
2006	03-04 Mar	Diwa	Severe Tropical	220 km North North	126	1005.7
2007	22-25 Feb	Gamede	Tropical Cyclone	230 km North West	158	995.5

Source: Arranged by JICA Expert Team based on the data obtained from
http://mauritiusattractions.com/cyclones-in-mauritius-i-109.html



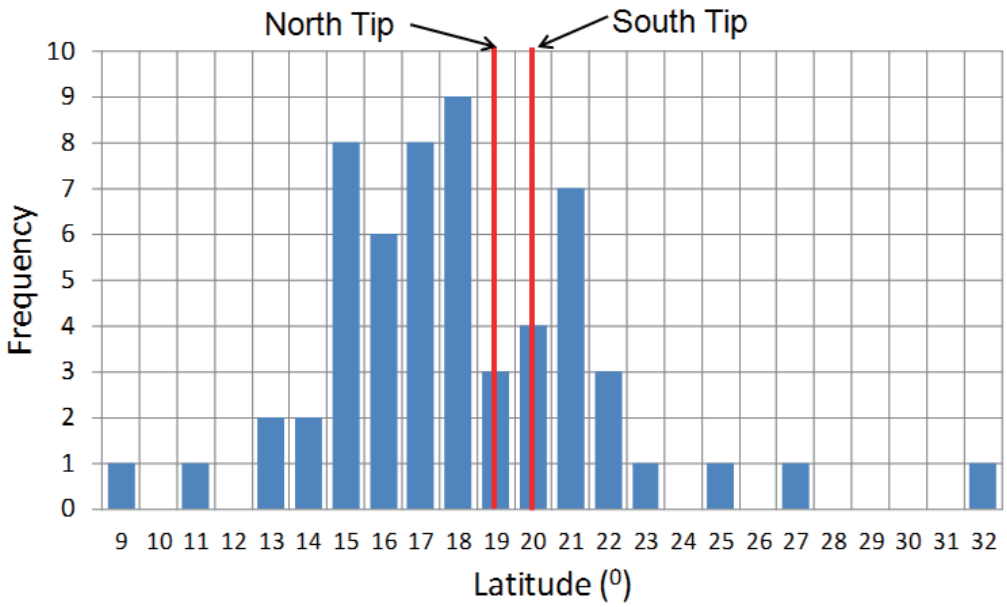
Source : Arranged by JICA Expert Team based on the data from JTWC, Cyclone Best Track

Figure 2.2.12 Tracks of Cyclones A (1990 -2000)



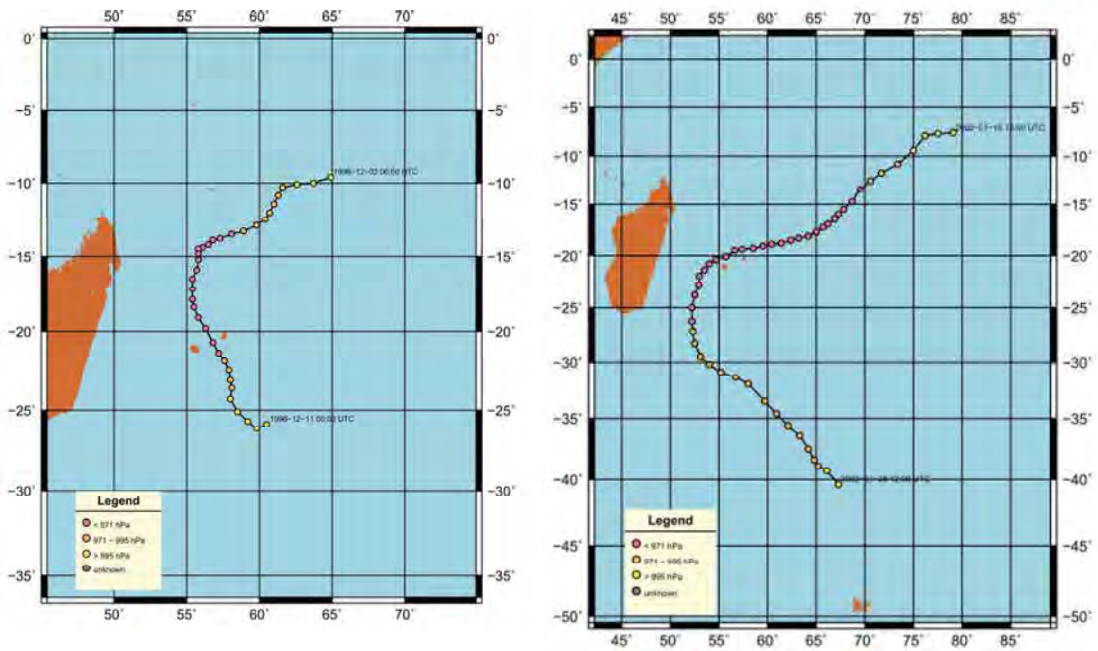
Source : Arranged by JICA Expert Team based on the data from JTWC, Cyclone Best Track

Figure 2.2.13 Frequency of Cyclones



Source: JICA Expert Team

Figure 2.2.14 Location of Cyclones with Lowest Pressure (describing southern and northern edge of Mauritius)



Daniella,1996 Dina,2002

Source: Arranged by JICA Expert Team based on http://www.bom.gov.au/cyclone/history/tracks/index.shtml

Figure 2.2.15 Typical Cyclone Tracks and Pressure Distribution in Case that the Lowest Pressure Occurs in Northern Part of Mauritius

2.2.4 Characteristics of Oceanography

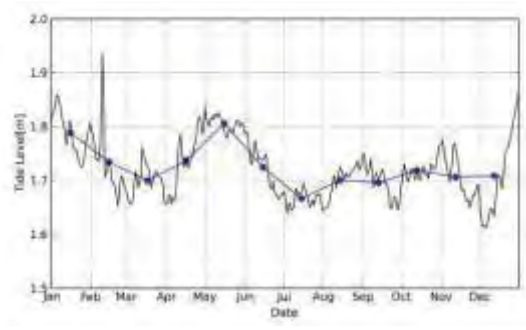
a. Water Level (Astronomical tide levels, water level rise due to abnormal tide and climate change)

Tidal level has been observed intermittently at Port Louis. Continuous tide observation has been undertaken since 1986. Figure 2.2.16 shows the time series of annual daily and monthly average in 1994 and 2003. Although the tide changes seasonally, it can be seen that the tidal level rises locally caused by cyclones around from January to March, while it is lower from May to October. This rise is mostly in correlation to the occurrence of cyclones.

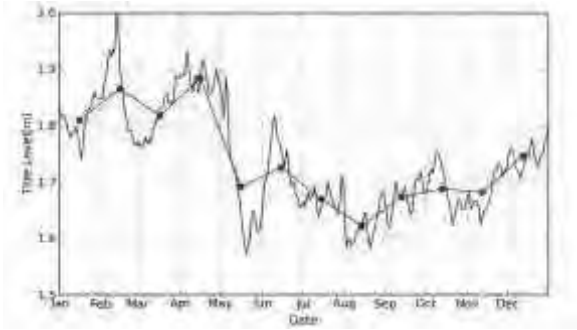
In the previous study report (Tidal Analysis and Prediction in the Western Indian Ocean), the harmonic decomposition has been carried out in Port Louis and Rodrigues and the harmonic constant has been described.

Table 2.2.4 shows the harmonic constant of main component tides. As a result, it can be seen that tides on half-day period is dominant.

Figure 2.2.17 shows the mean daily tide level for 30 years. From this figure, it can be seen that the tide level in Port Louis is rising 3.9mm per year. The value is not included the change of ground level. The tide observation has been carried out in Mauritius. However, there is not the design tide level to design the coastal structure. In this study, the design tide is to be analyzed using the tide observation results collected. Result of analysis will be described hereafter as part of the design condition.



Year 1994 (Hollanda)



Year 2003

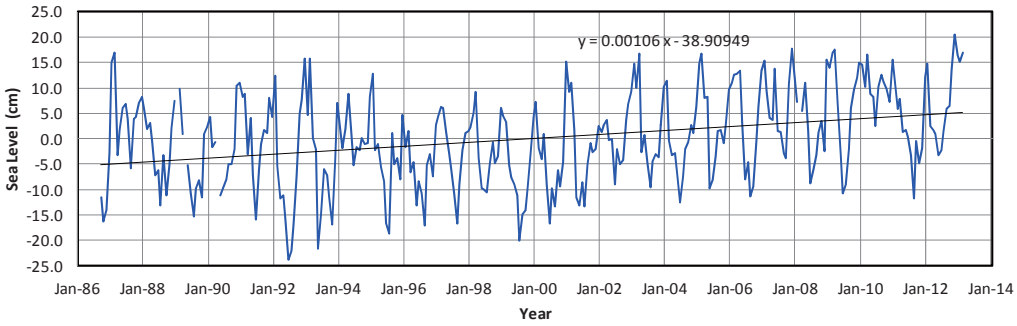
Source: JICA Expert Team

Figure 2.2.16 Time Series of Annual Tidal Level (in Port Louis)

Table 2.2.4 Harmonic Constants

Symbol	Constituent name	Port Louis		Rodrigues	
		Amplitude (cm)	Phase (deg)	Amplitude (cm)	Phase (deg)
M_2	Principal lunar semidiurnal	15.16	350.49	41.34	335.53
S_2	Principal solar semidiurnal	10.17	38.13	25.19	43.78
N_2	Larger lunar elliptic semidiurnal	4.29	86.51	7.59	59.48
K_1	Luni-solar declinational diurnal	6.35	286.94	5.54	315.04
K_2	Luni-solar declinational semi diurnal	2.23	184.67	6.12	181.61
O_1	Lunar declinational diurnal	4.18	263.33	3.44	296.72
SA		12.14	228.34	13.43	252.07

Source: Tidal Analysis and Prediction in the Western Indian Ocean Regional Report)



Source: JICA Expert Team

Figure 2.2.17 Time Series of Tides in Port Louis

b. Wave (Off-shore Wave)

In Mauritius, the wave observations have been carried out continuously at two points, namely Blue Bay (by MMS) and Roches Noires (by MOI). Figure 2.2.18 shows the location of these points. Location of observation station in Blue Bay has been changed, while MOI has started observation since February in 2012. In this study, the seasonal characteristic of waves have been analyzed based on the wave data collected. Also, additional wave recorder and current meters have been installed in this study to continue the wave observations since February 2013. Details of data collection status is shown in the Supporting Report (9. Wave Observation Data).

Blue Bay(MMS)

Roches Noires (MOI)

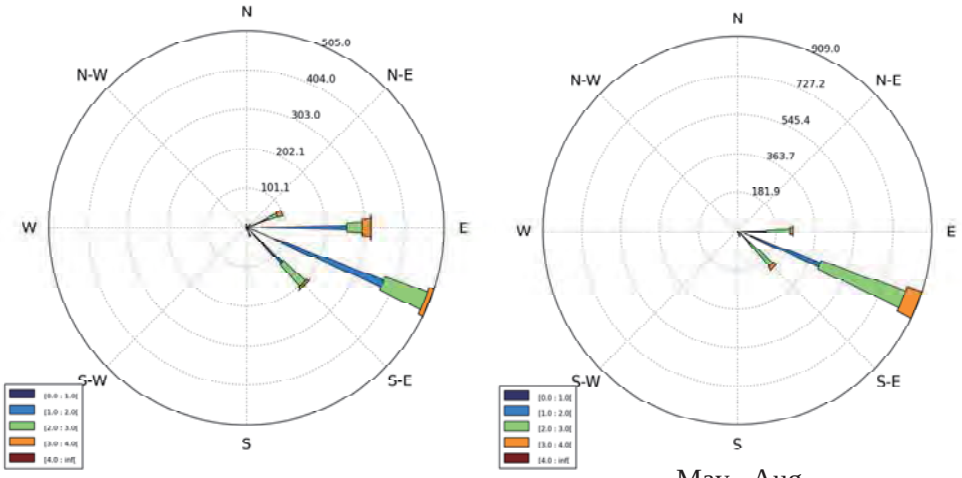
Source: Quoted from JICA Expert Team and WAVEDATA SUMMARY(MOI)

Figure 2.2.18 Location of Observation Station of MMS, MOI

Figure 2.2.20 shows a sample of observation result for off-shore waves. In July 2013 of winter season, the significant wave height is approximately 2.0 m. In Blue Bay, it is mostly over 2.0 m. There is no particular correlation on waves between Blue Bay and Roches Noires in this period. While in summer season, the significant wave height is over 4.0 m in some cases due to the influence of cyclones (Cyclone Edilson hit in February as shown in the below figure). After cyclone, the significant wave height decreases to 2.0 m or less. Wave roses in Roches Noires are shown in Figure 2.2.19. Wave direction of ESE is dominant in both winter and summer season at observation points. It is also observed that the wave height of 2-3m are common in

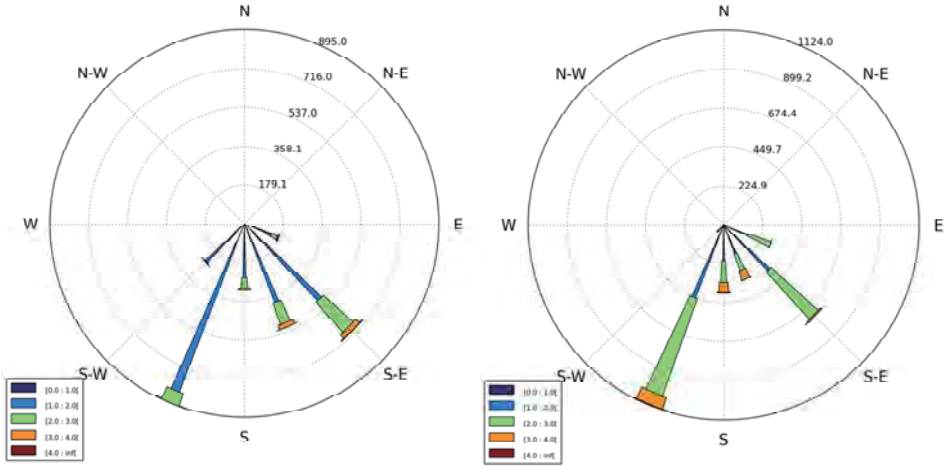
winter, while 1-2m are common in summer.

As a result of the above observations, the significant wave height is mainly influenced by the south-east trade winds in winter, and it will be less influenced in summer. When the cyclone comes, however, it would be over 4.0 m.



Nov. – Feb. May –Aug.

Roiches Noires

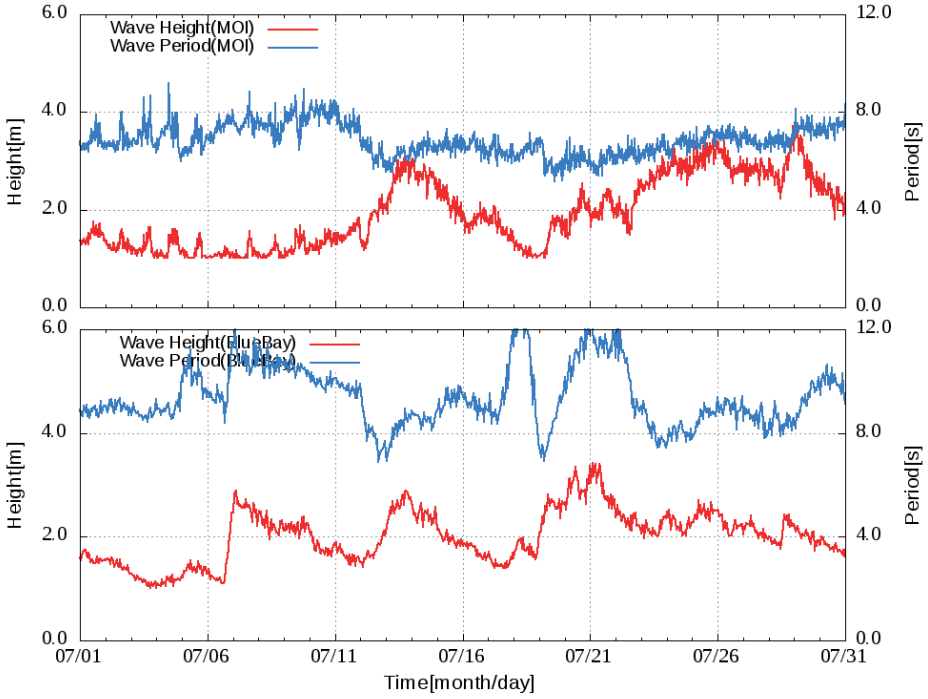


Nov. – Feb. May –Aug.

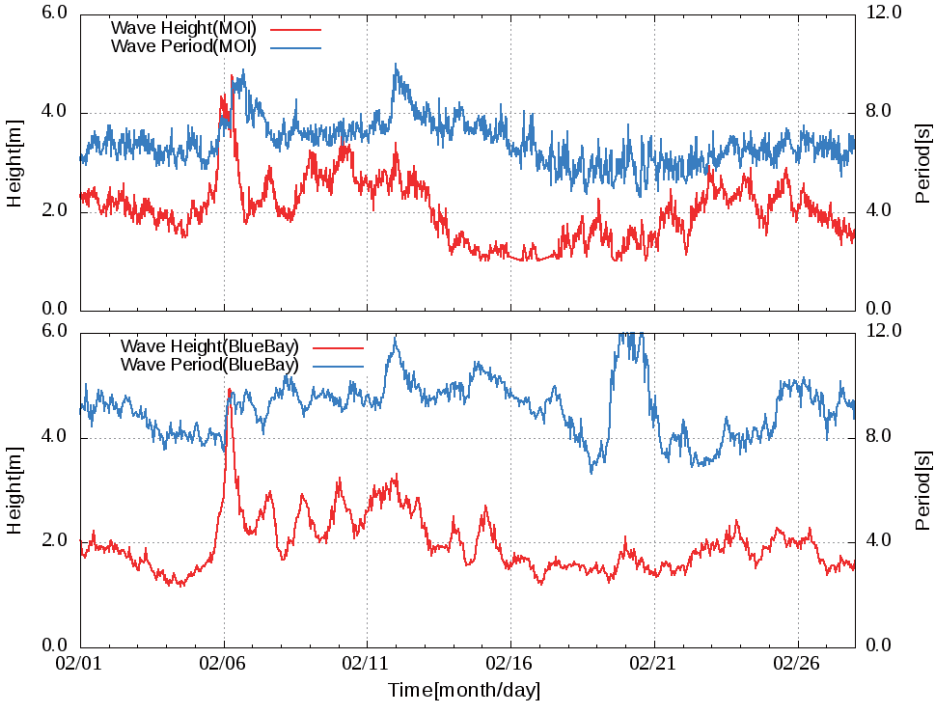
Blue Bay

Source: JICA Expert Team

Figure 2.2.19 Wave height/direction at Roches Noires (MOI) & Blue Bay



July in 2013



February in 2014

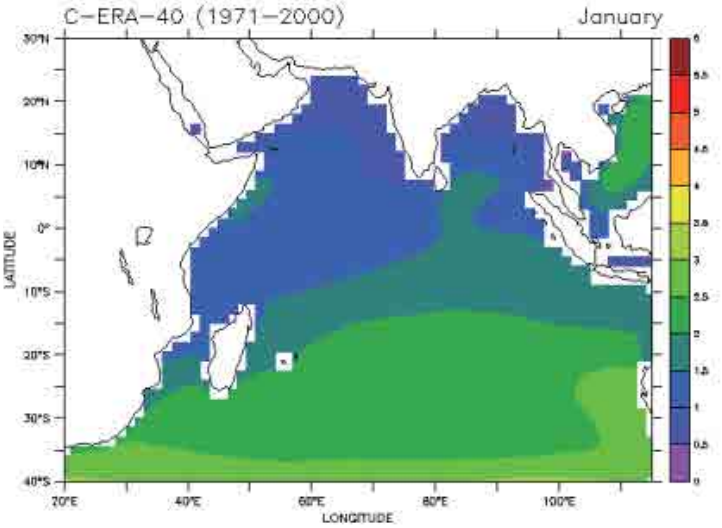
Source: JICA Expert Team

Figure 2.2.20 Wave Observation Result (Blue Bay and Roches Noires)

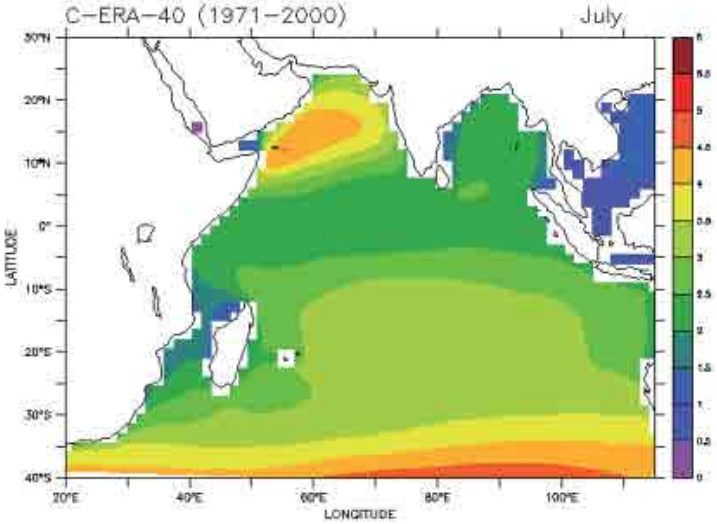
According to the observation results at Blue Bay (MMS) and Roches Noires (MOI), it has been understood that the average wave height is higher mainly because of the south-east trade winds

in winter, and it will be less influenced in summer except for the influence of cyclones. Also, ERA-40 Atlas issued by ECMWF (European Centre for Medium-Range Weather Forecasting) has conducted analysis (re-analysis based on the past data) on the significant wave heights in major seasons as shown in Figure 2.2.21 as below.

This results show that the average height of significant wave in summer is 1.5-2.5m, while 2.5-3.5m in winter. It is judged quite similar to the average value obtained in this study. Furthermore, it also be confirmed that the wave height in eastern part is higher than other parts due to the influence by the south-east trade winds in winter. It is found that the normal wave distribution is different between summer season and winter season if there is no cyclone in summer as well.



Average Height in January

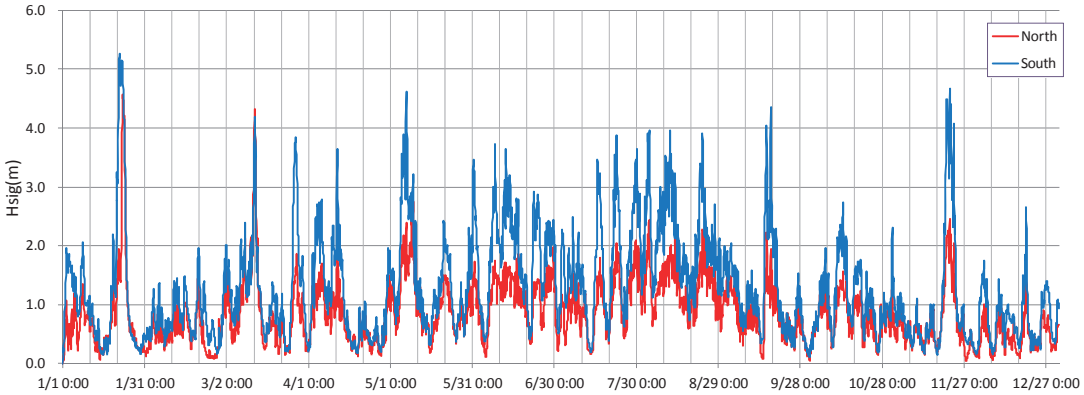


Average Height in July

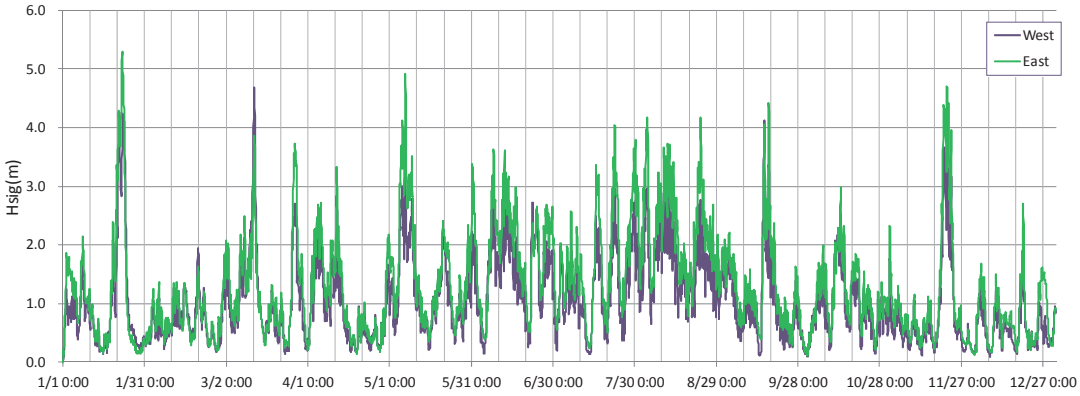
Source: ECMWF, ERA-40 Atlas

Figure 2.2.21 Distribution of Average Height of Significant Wave (Re-analysis by ERA-40, 1971-2000)

The temporal wave height changes were hindcasted in order to understand the wave characteristics in a year around Mauritius. The winds used in the hindcasting were revised NCEP/NCAR data. In the NCEP/NCAR data, the past 50 years of wind data are stored in databases. In the study data for one year, 2002, was used. The data includes the recent data of Cyclone Dina, which was a typical cyclone to make landfall on Mauritius. Time series of significant wave heights are shown in Figure 2.2.22. In the figure the wave height in the south point is higher than in the north. This is caused by the stronger winds in the south than in the north as shown in the wind distribution of Figure 2.2.11. If we compared the east and the west, the east is higher than in the west though the difference is not large between the south and north. Especially in winter the waves caused by the southeast trade winds are frequently over 2 m compared to those from the north, east and west. In summer the waves are 1.0m to 1.5m on average. Sometimes waves over 4m are caused by cyclones or low pressure. The cyclone hit in January and generated waves of higher than 5m. Actually the waves are likely to be higher than estimated because of the effects of local winds.



South and North Points



East and West Points

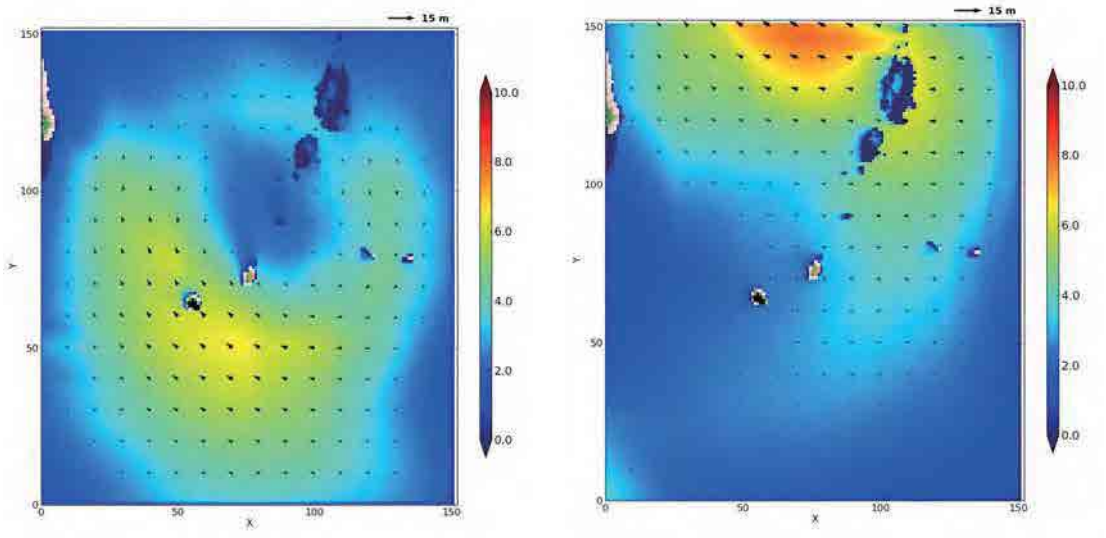
Source: JICA Expert Team

Figure 2.2.22 Time Series of Wave Height from Wave Hindcasting at East, West, North and South Points around Mauritius

The typical wave height distributions are shown in Figure 2.2.23 from the hindcasting results. At the time of cyclone or low pressure, high waves are generated around Mauritius

The characteristics of waves in a year are as follows from the time series and spatial distribution of wave heights from the hindcast.

- The significant waves frequently exceed 2m in height from March to September around Mauritius. At the south and east coasts, the high waves are frequent and caused by the southeast trade winds
- From October to April the waves are relatively moderate and 1m to 1.5m in height. At the north coast, the waves are low compared to other areas.
- The cyclone and low pressure hit Mauritius frequently from November to March. They produce high waves all around Mauritius. The significant waves are more than 5m in height though the height is different according to the track of a cyclone.



At the time of Cyclone Dina(2002/1/21)

At the time of Winter Low Pressure (2002/5/7)

Source: JICA Expert Team

Figure 2.2.23 Distribution of Significant Wave Height by Wave Hindcasting (Wind Distribution from revised NCEP/NCAR data)

c. Wave (High Wave caused by Cyclone)

According to the observation result aforementioned, the significant wave height of off-shore waves caused the cyclone Edilson in 2014 were found to be over 4.0 m. In the past, high waves over 10.0 m caused by cyclones passing nearby Mauritius have been recorded. Particularly, the cyclone produced coastal erosion in a short time. In this study, the wave forecasting has been conducted based on the estimated wind velocity calculated from the track and pressure of the past cyclones. In the wave forecasting, the maximum significant wave height in the four directions (East, West, North and South) of Mauritius was assumed by SWAN (wave forecasting model). In order to simulate and tuning of the wave forecasting model, the assumption value has been evaluated by comparing to the real data of Cyclone Giovanna in 2012. Figure 2.2.24 shows the above evaluation result. It is clearly confirmed that wave height and period at peak time is sufficiently correspondent to those of Cyclone Giovanna, although these were underestimated before the occurrence of cyclones.

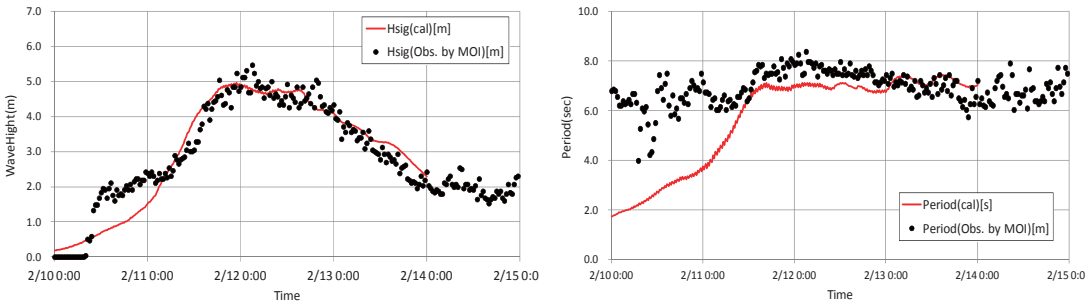
Using this model, time series of wave height at the objective points has been calculated based on the pressure longitude and distribution which is assumed from the track of the representative cyclone (JTWC). Table 2.2.5 shows the maximum significant wave height for each major cyclone in certain time period. Wave heights over 10.0m were observed throughout Mauritius at the time of Carol in 1960, Hollanda in 1994 and Dina in 2002. This study says

aforementioned that the cyclone is stronger in northern part, however wave forecasting shows the opposite results in some cases. This was caused by the strong waves occurred in the southern part of Mauritius when the clock-wise wind of cyclone passed through the coastal area in Mauritius. In addition, the result of wave forecasting made by Era-40 includes the waves in all situations, not only cyclones. It can be seen that the wave distribution is relied on the seasonal conditions, while that may be relied on the track and scale of cyclone when the cyclone occurs.

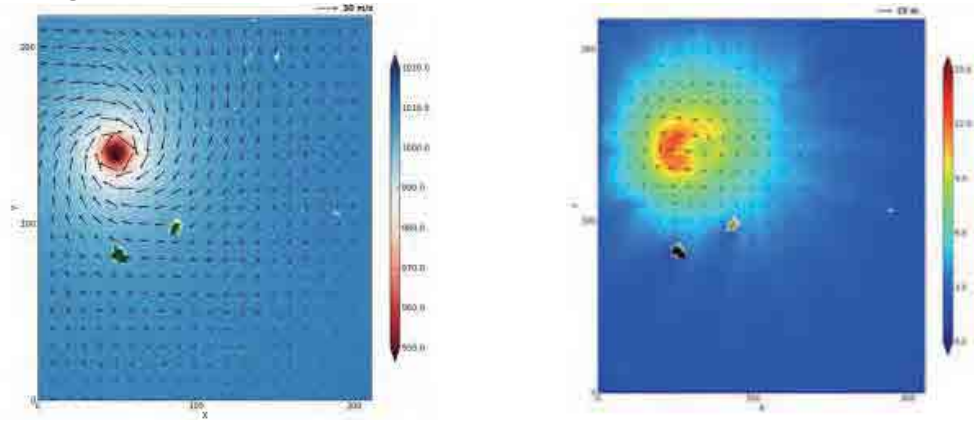
Table 2.2.5 Result of Wave Forecasting on Each Cyclone
(Max. Significant Wave Height)

Cyclone	Maximum significant wave height(m)			
	N	S	E	W
1960-Carol	12.51	10.94	14.00	12.61
1989-Krisy	5.07	5.76	6.26	5.44
1994-Hollanda	10.66	12.94	13.51	10.49
1995-Ingrid	6.13	8.68	8.37	6.94
1996-Bonita	5.91	4.08	5.25	4.28
1996-Daniella	7.38	6.02	7.69	10.28
1996-Flossy	3.66	5.42	5.19	4.25
1998-Anacelle	7.45	9.63	9.90	8.11
1999-Davina	7.79	9.49	10.59	11.37
2000-Connie	8.67	12.29	12.94	8.72
2002-Dina	11.78	10.12	11.49	7.41
2002-Guillaume	8.67	12.29	12.94	8.72
2003-Gerry	8.92	8.60	10.44	6.71
2005-Hennie	5.40	5.67	6.17	4.78
2007-Gamede	5.22	3.53	4.53	4.37
2008-Hondo	2.90	2.17	2.86	2.40
2009-Gael	3.12	2.21	2.86	2.95
2010-Gelane	3.32	3.17	3.65	2.15
2012-Giovanna	5.13	3.69	4.84	3.81
2013-Dumile	2.52	2.06	2.37	2.98
2013-Imelda	3.19	2.83	3.31	2.20

Source: JICA Expert Team



Wave height　　Period

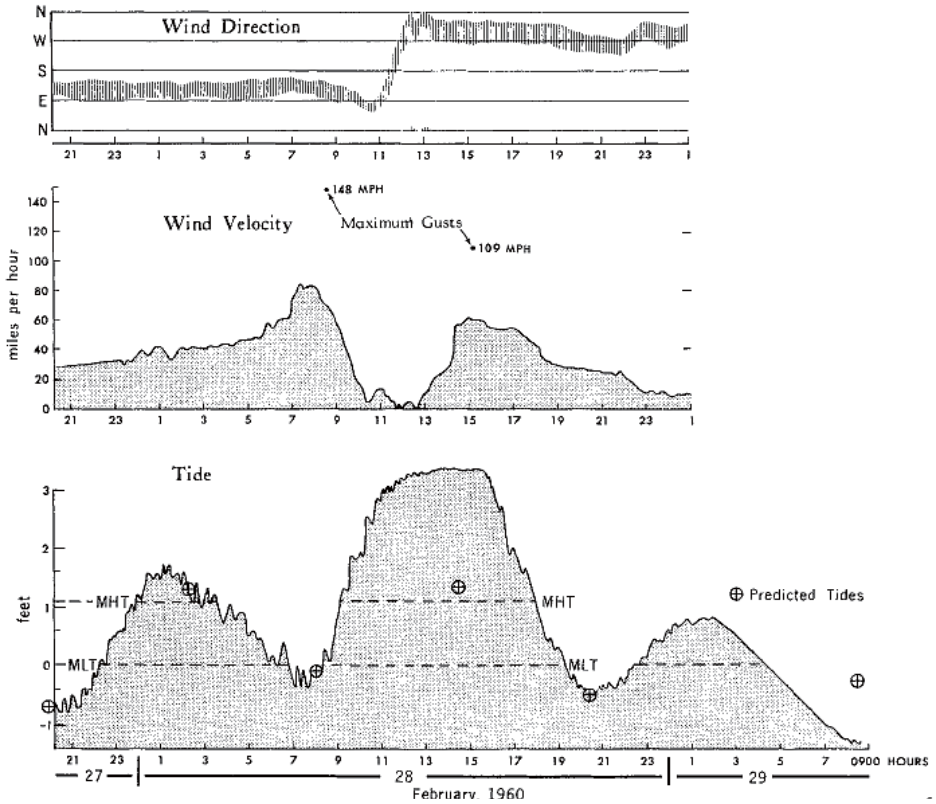


Wind velocity/pressure distribution　　Significant wave height distribution

Source: JICA Expert Team

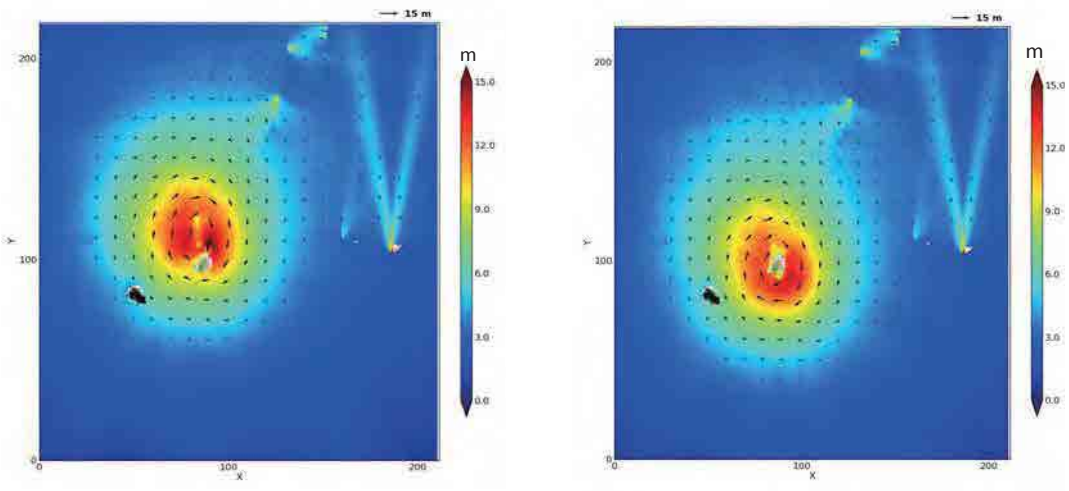
Figure 2.2.24 Verification Result of Cyclone, Giovanna

Cyclone Carol caused extensive damage in Mauritius in 1960. Wave run-up identified by field survey, erosion situation and observation record at that time are recorded in *Tropical Cyclones and Coastal Morphology in Mauritius* (refer to Figure 2.2.25). Based on that record and cyclone information by Cyclone JTWC about track, wave forecasting for Cyclone Carol was conducted. Figure 2.2.26 shows the significant wave height distribution at a discretional time. This result clearly shows that Cyclone Carol has still kept similar strength after reaching to the shore of Mauritius, so that wave was quite high in not only northern part but also southern part. Figure 2.2.27 shows the height of waves at the time. Although the wave height relies on the bathymetry, reef width and so on, the wave height of 12 feet was recorded in southern part of Mauritius. It is consistent to the result of wave forecasting abovementioned. Finally, it is confirmed that the significant wave height can be more than 10m depending on the track and power of cyclones in Mauritius.



Source: Tropical Cyclones and Coastal Morphology in Mauritius

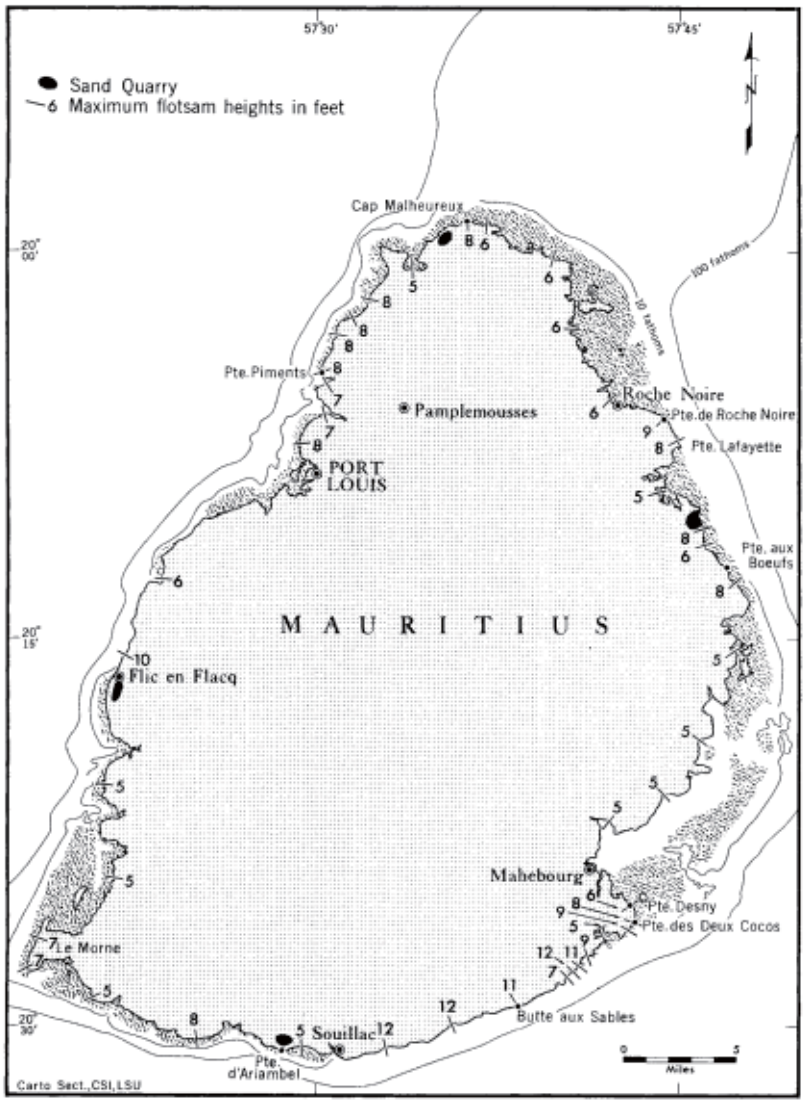
Figure 2.2.25 Observation Record of Cyclone Carol



1960/2/28 6:00UTC　　1960/2/28 12:00UTC

Source: JICA Expert Team

Figure 2.2.26 Wave Forecasting for Cyclone Carol



Source: Tropical Cyclones and Coastal Morphology in Mauritius

Figure 2.2.27 Wave Rising Elevation of Cyclone Carol (unit:feet)

d. Wave (at the lagoon)

In Mauritius, two institutions own one wave recorder each, MMS and MOI. In this study, considering the effective technical transfer for the use of wave recorder on both field work and data processing in the beginning, it is recommended to conduct the joint measurement in cooperation with related institute or agency of Mauritius and JICA Expert Team. The following two main objectives are thought as the measurement using Wave Hunter.

- Objective-1: Long term wave observation at fix point of outer reef area. (There was no station for wave observation at west coast area. Thus, it is suggested to do the wave observation at northwest or southwest coast area)
- Objective-2: Wave and current measurements inside of the lagoon to examine the mechanisms of external forces (waves and currents) for sediment transport and resulting beach change.

From the above mentioned two objectives, the Objective-2 is recommended as the 1st trial measurement taking into account the easiness of installation work on site. It was decided to install the wave recorders and the current meters to obtain wave observations at Pointe d'Esny. There are several coasts that the further detail information for the mechanism of sediment transport inside of the lagoon is required (e.g., Albion, Flic en Flac, Le Morne, Pointe d'Esny). The configuration of coastal line at Pointe d'Esny has a curvature from south to north. Due to this, the distance from the reef edge to the shore and the direction of incident waves are significantly different at south and north area. The effect of such differences might affect the characteristics of sediment transport in the south and north area, also coastal deformation as well as coastal erosion. Observations inside a lagoon is relatively easy as far as survey work goes, therefore lagoons can be recommended as an ideal place for technology transfer.

By working to gain a clear understanding of the difference of the characteristics of waves and currents at south and north area, and the impact of such mechanisms on littoral transport at Point d'Esny, will contribute to the planning and design of beach conservation measures at Pointe d'Esny.

Figure 2.2.28, Figure 2.2.29 show a bird's-eye-view of Pointe d'Esny and the condition of the installed wave recorder. Observation using the wave recorder began in February 2013 and has been recorded continuously.

Figure 2.2.30 shows the relation between the water depth and the significant wave height which was obtained by the observation from February to May. From this figure the correlation between change of the depth and the change of wave height can be observed. The relation between the depth and the wave height is roughly H = 0.09d (H: wave height, d: depth) at the site in the south and H = 0.07d at the site in the north. Figure 2.2.31 shows the results which are compared with the result in Blue Bay. The cyclone Imelada passed in the beginning of April, and the relation can be clearly observed at this time.

In October 2013, one of the two wave recorders installed at Pointe d'Esny was moved to Grand Sable. Setting condition and location is shown in Figure 2.2.32. After that, two cyclones hit Mauritius during January to February in 2014. Tracks of cyclone Bejisa and cyclone Edilsonis are shown in Figure 2.2.33. Also, the wave height change in Grand Sable and Roiches Noires at that time is shown in Figure 2.2.34. When cyclone Bejisa hit, the significant wave height at offshore was around 3.0m, while the wave height at the lagoon was only 0.3m.

In case of cyclone Edilson, wave height was 4.0m at offshore while 0.3m in the lagoon. Wave height increased slightly, however neither cyclone caused major changes to the situation. At Grand Sable, wave power is attenuated since there is 4 km between beach and the reef edge. In this situation, wave height at the lagoon is not much affected by that of offshore. Furthermore, cyclone Bejisa passed through at western part of Mauritius, on the other hand, cyclone Edilson passed through at eastern part. This might be the main reason that the wave height being observed at Roiches Noires is rather different for the two cyclones.

As a result of the aforementioned investigations, the characteristic of waves in Mauritius are summarized as below:

1) Waves from the south (mostly from SSW-ESE; significant wave height: 2.0-3.0m): considered to be caused by strong winds which occur in southern part of Mauritius in winter season.

2) Waves created by south-easterly trade winds (mostly from SSW-ESE; significant wave height: 2.0-4.0m): considered to be caused by south-easterly trade winds hitting the Mauritius coast in winter season.

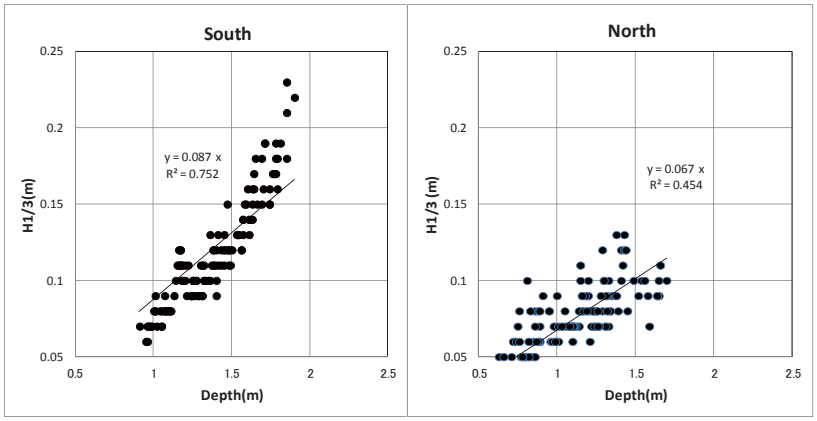
3) High wave caused by cyclones (significant wave height: approx. 4.0-10.0m; depends on the track of the cyclone *no large cyclones occurred during the observation period): Cyclones often pass though from North to South. High waves are caused by the waves generated by clockwise winds. During observation period waves over 4.0m were observed.

Source: JICA Expert Team

Figure 2.2.28 Wave Recorder/Current Meter location

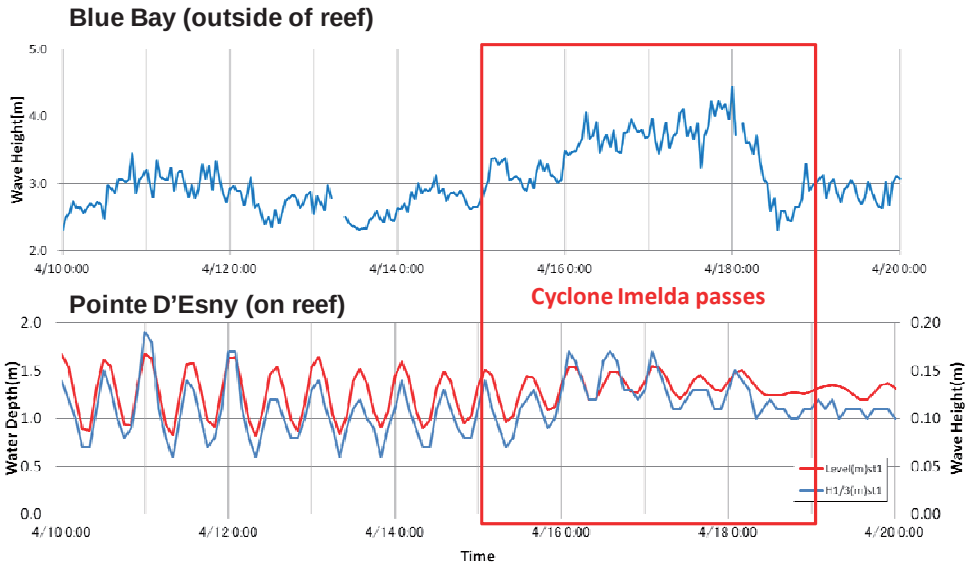
Source: JICA Expert Team

Figure 2.2.29 Installation of Wave Recorder



Source: JICA Expert Team

Figure 2.2.30 Relation between Depth & Wave Height



Source: JICA Expert Team

Figure 2.2.31 Comparison of Wave Forecasting between Blue Bay & Pointe d'Esny

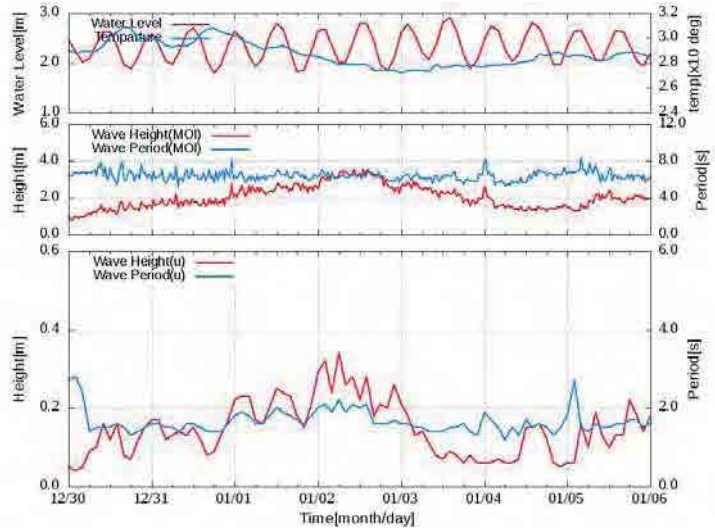
Source: Arranged by JICA Expert Team based on Google map

Figure 2.2.32 Observation Points (Roiches Noires & Grand Sable)

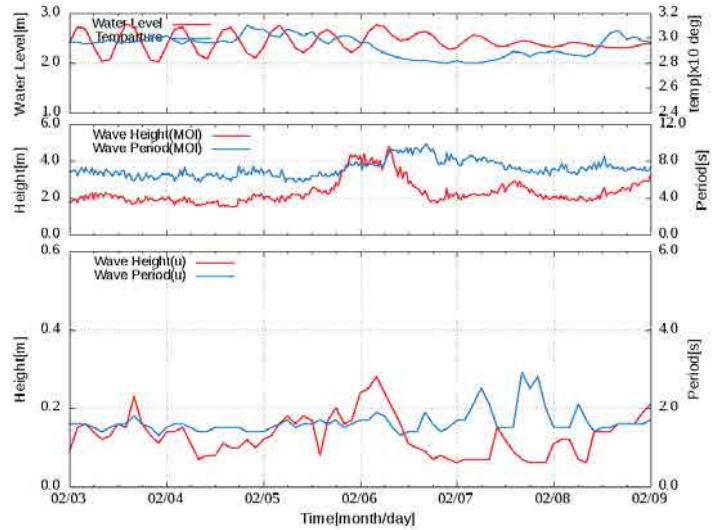
Cyclone Bejisa　　Cyclone Edilson

Source: JICA Expert Team

Figure 2.2.33 Cyclones Occurred in 2014



At the time of Cyclone Bejisa



At the time of Cyclone Edilson

Source: JICA Expert Team

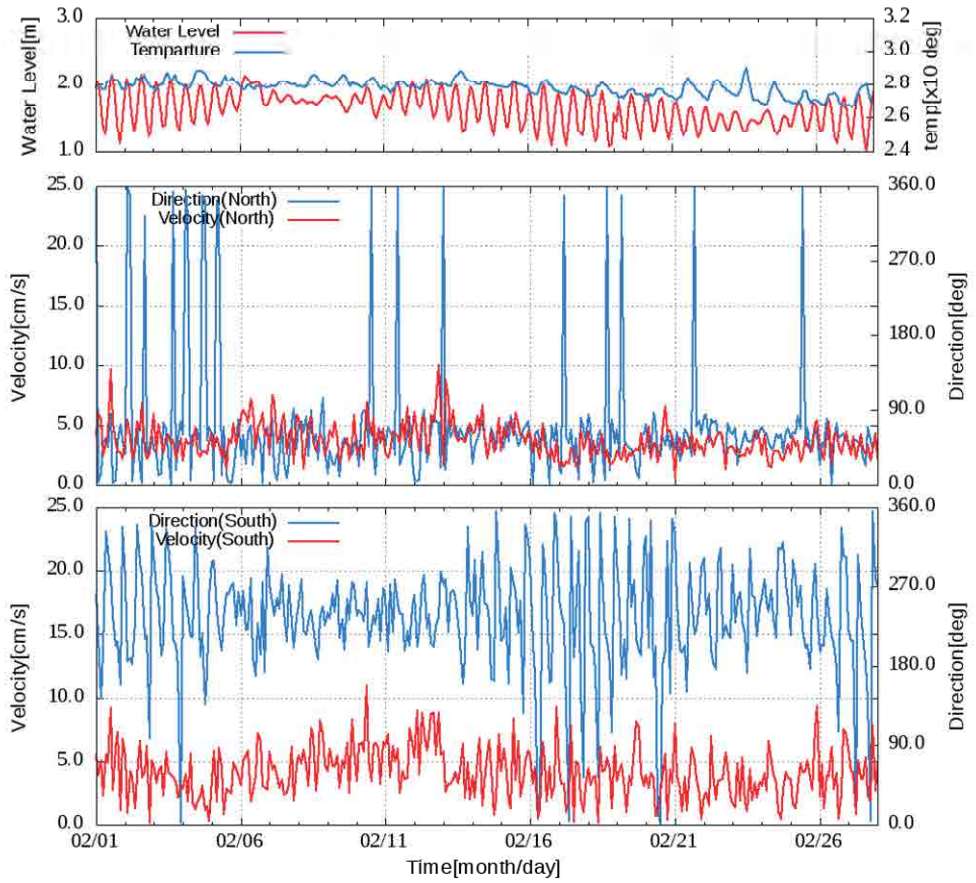
Figure 2.2.34 Change of Wave, Water Level, Temperature during Cyclones

e. Current (in the lagoon)

Currents in the lagoon have been observed continuously since February 2013 by two wave recorder stations and two current meter stations at Pointe d'Esny as shown in Figure 2.2.28. Flow velocity and flow direction (at two current meter stations) at the time of cyclone is shown in Figure 2.2.35. The results shows that no remarkable changes were found on flow velocity before or after a cyclone. It means that flow velocity may not be changed by cyclones, but is influenced by tides.

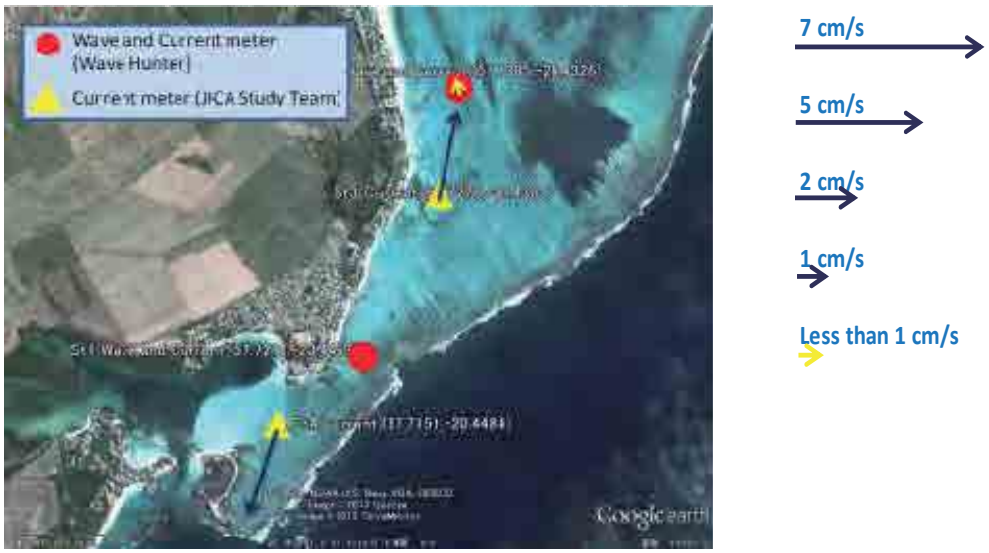
Vectors of current flow velocity from four observation points during cyclone Edilson are shown in Figure 2.2.36. The result shows that the majority of obtained velocity values are less than 10cm/s. Current meter in the northern part shows current direction is facing north. It is thought that the shore current is developing at this point. While, current meter in the southern part shows current direction is mostly facing south to west. It is thought that it is not the shore current, but it is the effect caused by the tide.

Finally, it is obvious that flow velocity in the lagoon is generally small and the shore current which is generated by offshore waves occurs quite rarely. Current occurs predominantly because of tide effect and/or wind disturbance.



Source: JICA Expert Team

Figure 2.2.35 Time Course of Flow Velocity/Direction at Pointe D'Esny (in Feb. 2014)



2014 2/5 8:00

2014 2/6 12:00

2014 2/7 12:00

Source: JICA Expert Team

Figure 2.2.36 Distribution of Flow Velocity/Direction at the time of Cyclone Edilson

2.3 Socio-Economic Conditions, National Policy, Legal Framework, Organization

2.3.1 Socio-Economic and Financial Conditions

a. Economic Condition

Table 2.3.1 shows the recent trend of GDP by industry for three years (2012-2014), indicating an annual growth of some 6%. Manufacturing shares about 16% in 2014 while hotels and restaurants which have strong relationship with tourism accounted for about 6% of GDP.

Table 2.3.1 GDP by Industry (2012-2014)

Unit：Million Rs

Category	2012	2013	2014
Agriculture, forestry and fishing	10,494	10,405	10,308
Mining and quarrying	1,000	990	975
Manufacturing	50,537	55,021	56,447
Electricity, gas, steam and air conditioning supply	4,092	4,491	5,290
Waste supply; sewerage, waste management and remediation activities	1,193	1,264	1,323
Construction	19,034	17,680	16,422
Wholesale & retail trade; repair of motor vehicles and motorcycles	36,807	39,705	42,870
Transportation and storage	17,797	18,763	19,983
Accommodation and food service activities	21,249	19,697	21,512
Information and communication	13,478	13,938	14,663
Financial and insurance activities	31,262	32,799	35,301
Real estate activities	16,665	17,784	18,922
Professional, scientific and technical activities	13,882	15,407	17,018
Administrative and support service activities	7,640	8,493	9,418
Public administration and defense; compulsory social security	17,984	21,283	22,743
Education	13,413	15,428	16,293
Human health and social work activities	11,698	13,768	15,245
Arts, entertainment and recreation	8,826	9,903	10,912
Other service activities	5,566	6,119	6,644
Gross Domestic Product at basic prices	**302,617**	**322,938**	**342,287**

Source: National Accounts, Statistics Mauritius, MoFED

b. Tourism

b.1 Tourist

Mauritian tourism, the third biggest industry after manufacturing and agriculture in the nation has contributed to the nation's economy and it is indispensable in economic development. Table 2.3.2 shows the tourist arrivals for the years 2006-2014. The number of tourist is increasing at around 4.0% annually on average. Duration of stay per tourist is about 11 days on average.

Table 2.3.2 Tourist Arrivals (2006-2014)

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
All Countries	788,276	906,971	930,456	871,356	934,827	964,642	965,441	993,106	1,038,906

Source: International Travel and Tourism Year 2014, MoFED

Table 2.3.3 shows gross earnings from tourism for the years 2006-2014 according to a survey by the Ministry of Tourism and Leisure.

Table 2.3.3 Gross Earnings from Tourism (2006-2014)

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
Rs. Million	31,942	40,687	41,213	35,693	39,456	42,717	44,378	40,557	44,304

Source: International Travel and Tourism Year 2014, MoFED

b.2 Hotels

The number of hotels registered in Mauritius was 112 as of December 2014. Table 2.3.4 indicates the number of rooms, 12,799, and the number of beds, 26,174, in hotels that were operating as of this time.

Table 2.3.4 Number of Hotels, Rooms and Beds (2005-2014)

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
No. of Hotels	99	98	97	102	101	112	109	117	107	112
No. of Rooms	10,497	10,666	10,857	11,488	11,456	12,075	11,925	12,527	12,376	12,799
No. of Beds	21,072	21,403	21,788	23,095	23,235	24,698	24,242	25,496	25,105	26,174

Source: International Travel and Tourism Year 2014, MoFED

Large hotels with more than 80 rooms account for 53 hotels. It is 47% of the total number of hotels in operation. The number of rooms in large hotels was 9,605 and the number of beds was 19,776 in 2014, which is equal to 75% of the total in Mauritius. Table 2.3.5 indicates room and bed occupancy ratios for the years 2007-2013, showing a leveling-off trend. Also, the current room occupancy ratio was 65% while bed occupancy ratio was 57%.

Table 2.3.5 Room and Bed Occupancy Rates of Large Hotels (2007-2014)

Year	2007	2008	2009	2010	2011	2012	2013	2014
Room Occupancy	78	70	62	66	65	65	65	67
Bed Occupancy	70	62	55	58	57	57	57	60

Source: International Travel and Tourism Year 2014, MoFED

c. Financial Conditions

c.1 National Budget

In 2006-07, the Mauritian government launched an economic reform program and as part of fiscal management reforms, it was decided to reform the budget process by introducing a Program-Based Budget (PBB) in the context of a Medium-Term Expenditure Framework (MTEF). The indicative PBB was submitted alongside the traditional line-item budget in 2007-08 as a starting point and in order to give the Ministry of Finance and Economic Empowerment (MoFEE) the opportunity to update the necessary systems required for full implementation.

Then, a fully-fledged PBB (budget year 2008-09) was embedded in a three year MTEF (2008-09 / 2010-11). The preparation of budget estimates under MTEF involves matching

Ministries/Departments requirements with total resources, based on the overall priorities. The process involves the preparation by ministries/departments of gender sensitive "strategic plans" in line with the priorities of the current government economic reform and in which ministries/departments define their programs with measurable outcomes, sub-programs with priority objectives, and outputs. On the basis of strategic plans, ministries/departments must produce an integrated budget that reflects the cost of policies.

The PBB outlines the outcome(s) at the program level, the priority objectives at the sub-program level, or at the program level when there are no sub-programs, and outputs of programs/sub-programs. Each ministry/department has to prepare annually a 3-fiscal-year rolling PBB statement. The budget proposals should be submitted as per the PBB statement, which include three parts, namely:

- Part A: Performance Information

- Part B: Financial Resources

- Part C: Human Resources

c.2 MOESDDBM Budget

c.2.1 Budgetary Program

According to PBB (year 2014), major and prior programs to be executed in compliance with the MOESDDBM Strategy in 2014-2016 are listed as below:

Program 401: Environmental Policy and Management

Program 402: Environmental Protection and Conservation

Program 403: Uplifting of the Physical Environment

Program 406: Sustainable Development

c.2.2 Budget for MOESDDBM

In order to implement the four programs, the budget for the MOESDDBM for the next three years is shown in Table 2.3.6. In Program 402 "Environmental Protection and Conservation", a budget for improvement, upgrading and rehabilitation of beaches is allocated and Rs 200 million for 2013, Rs 205 million for 2014-2016 are allocated. Program 404 "Community based infrastructure development, capacity building", program 405 "Ground drainage system" have been arranged by Ministry of Public Infrastructure (MPI) since 2011.

Table 2.3.6 Budget for MOESDDBM (Program Categories)

Unit:Rs

Code	Programmes	2013 Est.	2014 Est.	2015 Planned	2016 Planned
401	Environmental Policy and Management	168,361,000	74,622,000	74,255,000	75,941,000
402	Environmental Protection and Conservation	201,418,000	259,030,000	258,088,000	242,761,000
403	Monitoring, Uplifting and Embellishment of the Environment	198,890,000	234,918,000	224,684,000	239,548,000
406	Sustainable Development and Climate Change	7,164,000	7,739,000	2,828,000	2,919,000
	Total	575,833,000	576,309,000	559,855,000	561,169,000

Source: PBB2014, MoFED

Table 2.3.7 summarizes economic categories for the next three years. Budget for compensation of employees for 2014-2016 is maintaining upward trend.

Table 2.3.7 Budget for MOESDDBM (Economic Categories)

Unit: Rs

Code	Programmes	2013 Est.	2014 Est.	2015 Planned	2016 Planned
21	Compensation of Employees	219,780,000	227,685,000	235,692,000	243,079,000
22	Goods and Services	89,512,000	118,634,000	115,930,000	109,199,000
26	Grants	102,141,000	2,231,000	2,231,000	2,231,000
31	Acquisition of Non-Financial Assets	164,400,000	227,759,000	206,002,000	206,660,000
	Total	575,833,000	576,309,000	559,855,000	561,169,000

Source: PBB2014, MoFED

Table 2.3.8 presents budget for MOESDDBM for 2014 categorized by program and their types. The budget for compensation of employees (Rs 230 million) corresponds to about 40% of the total.

Table 2.3.8 Budget for MOESDDBM (PBB2014)

Unit: Rs

Code	Programmes	Compensation of Employees	Goods and Services	Subsidies/ Grants	Acquisitionof Assets
401	Environmental Policy and Management	45,500,000	24,891,000	2,231,000	2,000,000
402	Environmental Protection and Conservation	51,318,000	59,653,000	0	148,059,000
403	Monitoring, Uplifting and Embellishment of the Environment	128,198,000	29,020,000	0	77,700,000
406	Sustainable Development and Climate Change	2,669,000	5,070,000	0	0
	Total	227,685,000	118,634,000	2,231,000	227,759,000

Source: PBB2014, MoFED

d. Economic Evaluation

d.1 Economic Valuation

The gross earnings from tourism reached Rs. 40.5 billion in 2013 (according to the Bank of Mauritius), which is equal to expenditure per tourist multiplied by the number of tourist arrivals per year. Economic value of the coastal zone plays an important role enough to reach about 12% of the GDP in 2013. The proportion of national GDP of the tourism industry was 5.6% and 8.7% in 1997 and 2008, respectively, showing a gradual increase year by year.

Economic valuation of the coastal zone was studied by Landell Mills in 2009 in the Financial Strategies for ICZM Implementation. The report mentions that only about 2.4% of total government budget is allocated for coastal zone public sector investment although the coastal zone has contributed so much to the tourism industry, pointing out the importance of economic valuation of the coastal zone. The total economic value was estimated considering the values of 1) annual revenue streams by tourism and fishery industries, 2) leasehold premiums paid by hotels, cottages and rental houses, property valuations, and 3) travel costs, etc. as categorized in Table 2.3.9.

Table 2.3.9 Estimated Total Economic Value of Coastal Zone

Source	Rs	% of Total
Annual Revenue Stream	405,163,754,703	37.4%
Leasehold Premium	126,810,297,827	11.7%
Travel Cost	270,255,034,966	24.9%
Hedonic Pricing	75,089,632,008	6.9%
Total Property Value on the Coast	207,196,867,685	19.1%
Existence Value	237,787,940	0.022%
Total Economic Value	1,084,753,375,129	100%

Source: Development of ICZM Framework (Landell Mills, 2009)

d.2 Economic Impact by Coastal Projects

Economic impact of coastal projects is the expected economic benefit of projects to protect assets behind the coast (in the hinterland), and to promote coastal utilization, maintain the environment, and to preserve and improve coastal conditions.

Constructing coastal protection facilities will preserve the area behind the coast from extreme high tides and waves, and prevent the facilities from being damaged. In the case of Grand Sable, public facilities such as coastal roads and bus stops will be protected and damage to citizen's assets will be reduced and, as a result, economic loss to the commercial activities behind the coastal zone can also be reduced. Also, security and convenience in the coastal zone will be improved and value of land property will be increased accordingly.

From an environmental point of view, coastal projects will protect sandy beaches and reduce wave heights, as well as improving the scenery in the coastal zone. Improving water quality may create better environment for fisheries. In Mauritius, coastal projects will enhance the tourism industry and then the number of tourists and people who enjoy recreational activities can be considered to increase as the tourism industry plays an important role in the nation's

economic activities.

Such economic impact by coastal projects will be anticipated when selecting the 12 prioritized coasts in Mauritius for projects under the Project. Especially, the Mauritian coastal zone has a high economic value, and contributes to enhancing the nation's economic activities, and therefore, non-physical measure like maintaining the existing coastal conditions is proposed rather than physical measures.

e. Land use at the coastal zone

According to the Beach Authority, the number of public beaches is 90 and the total length of the public beaches is 39.3 km, representing 12% of the total coast length. Utilization of the coastal zone is shown in Table 2.3.10. Almost 23% of the coastal zone is used for agricultural land followed by bungalows and hotels.

Table 2.3.10 Land Utilization of Coastal Zone

Usage	Coastline (km)	%
Public Beaches	39.3	12%
Hotel Sites	41.9	13%
Bungalow Sites	52.0	16%
Building Sites	25.0	7%
Diverse Activities	12.8	4%
Agriculture	17.0	5%
Grazing	28.7	9%
Under Vegetation	76.2	23%
Coastal Road	16.1	5%
Cliffs	10.2	3%
Criffs/Grazing	11.5	3%
St. Antoine Sugar Estate	4.5	1%
Total	335.2	1.0

Source: Beach Authority

There are currently 20 sites shortlisted as public beach sites for marine protection and they are expected to attain designation as public beaches in the near future. Public beaches are located along sandy beaches, muddy beaches and rock beaches, and locals and tourists alike enjoy recreational activities according to the type of each. There are beach facilities, which are well maintained and cleaning service is conducted by private companies, which have a contract with the Beach Authority.

2.3.2 National Policy, Legal Framework, Organization

a. National Policy related to ICZM

The two main national policies related to coastal protection and disaster management in Mauritius are: 1) National Development Strategy (NDS: 2005) and 2) National Environment Policy (NEP: 2007). In those policies, the main issues related to ICZM are listed below.

<National policies related to ICZM>

i) To preserve the ecological integrity of the coastal zone ecosystems, including mangroves and coastal wetlands.

ii) To establish lagoon zones.
iii) To increase the number of Marine Protected Areas.
iv) To improve ecological assessment and monitoring of coral reef ecosystems.
v) To improve lagoonal water quality.
vi) To improve public access to prime beaches.
vii) To provide and upgrade public beach infrastructure and amenities.
viii) To control of beach erosion through appropriate technology.
ix) To harmonize coastal development with its surrounding environment taking into account its carrying capacity.
x) To encourage all tourism and tourism-related enterprises to adopt eco-labeling schemes and implement Environmental Management Systems.
xi) To minimize pollution from nautical activities.
xii) To improve islet management and development.
xiii) To protect and enhance the coastal heritage.

b. Legal Framework

There is no specific legal framework dedicated to ICZM. However, this can be referred from several existing legal frameworks. Main legal provisions related to ICZM are summarized as follows.

b.1 Definition of Coastal Zone

The coastal zone is defined as the area that is situated within 1 km from High Water Mark (H.W.M) extending either side into the sea or inland (**Environment Protection Act 2002, EPA 2002**). In Mauritius, H.W.M means the position or line of wave run-up, that is, it varies according to location and time and is substantially different from the tidal level.

b.2 Ownership in Coastal Zone

All of the coastal land (coastal zone) in Mauritius is the property of the nation (State Lands Act 1982) and is managed by the Ministry of Housing and Lands (MoHL). The coastal zone within 81.12m from H.W.M is designed to ensure access to the seashore and beaches by the public and is not available for private ownership (Pas Géométriques Act 1874, State Lands Act 1982). However it can be leased for commercial or residential purposes with the permission of MoHL.

b.3 Classification of Coastal Zone

The coastal zone in Mauritius is classified into four categories; 1) Public beach, 2) Leased area, 3) Vested area, and 4) Uncommitted area. Public beach encompasses “the space between the low water mark and the high water mark, and also the surrounding waters up to a distance of 100 metres” (Beach Authority Act 2004). Public beaches in Mauritius are designated by MoHL and since 2002 are managed by the Beach Authority. The classification of the coastal zone and its management bodies are summarized in the table below.

Table 2.3.11 Classification of Coastal Zone and its Management Body

Classification	Description	Main body	
		Implementation	Management and maintenance
1) Public beach	Public beach declared by MoHL	MOESDDBM	Beach Authority (MoLG)
2) Leased area	Leased area for private owner or company	Lessee (individual / company)	Lessee (individual / company)
3) Vested area	Leased area for Government organization	Lessee (Government organization)	Lessee (Government organization)
4) Uncommitted area	None of the above	MOESDDBM	District Council (MoLG)

Source: JICA Expert Team

b.4 Regulation of Buildings and Structures Landward from H.W.M

Regulation for buildings and structures in the coastal zone is defined in Design Sheet, Residential Coastal Development (2004). With the regulation, the setback area that is prohibited to construct any buildings /structures was revised from 15m to 30m from H.W.M. This regulation is applicable to not only newly leased area but also existing leased area when the lessee renews the lease contract. However, this regulation does not have legal force against existing lessees at the practical level. Types of structures that may be allowed exceptionally within 30m setback are; 1) jetties on piles, 2) wooden 'umbrella kiosks' that are open, supported by a single pole and that do not have a concrete or hard basement, and 3) slip ways not exceeding 20cm above datum.

Table 2.3.12 Regulations for Buildings and Structures Landward from H.W.M

Residential development	A Coastal Frontage	B Coastal Road	C Inland
Maximum Building height	G+1+33% (G)	G+2	G+2+50% (G)
Max Building Height in meters	13 m	15 m	18 m
Max Plot Coverage	20 %	40 %	40 %
General setbacks	No less than 30 m from HWM	No less than 30 m from HWM	
From main road (Class A + B)	6 m	6 m	6 m
Access Roads	4.5 m	4.5 m	4.5 m
Lightly trafficked roads	3.0 m	3.0 m	3.0 m
Side and rear boundaries	3.0 m	2.0 m	2.0 m

Note : G(Ground Floor Area)

Source: "Design Sheet, Residential Coastal Development, November 2004", MoHL

b.5 Regulation for Buildings and Structures Seaward from H.W.M

The Fisheries and Marine Resources Act, 2007 (FMRA 2007) provides that "no person shall place, construct or cause to be placed or construct any structure within the territorial sea or the internal waters, as defined in the Maritime Zones Act 2005, except with the written authorization of the Permanent Secretary"

b.6 EIA (Environmental Impact Assessment) Approval Process

In 1991, Mauritius adopted the EPA 1991, which was the first comprehensive environmental legislation. It introduced the concept of environmental impact assessment (EIA). In 2002, the EPA 1991 was repealed and replaced by the EPA 2002. In addition to the EIA, which remains the key instrument for the evaluation of environmental impact, the EPA 2002 introduced the concept of preliminary environmental report (PER). Approval process of EIA and PER is shown in the table below.

Table 2.3.13 EIA Approval Process

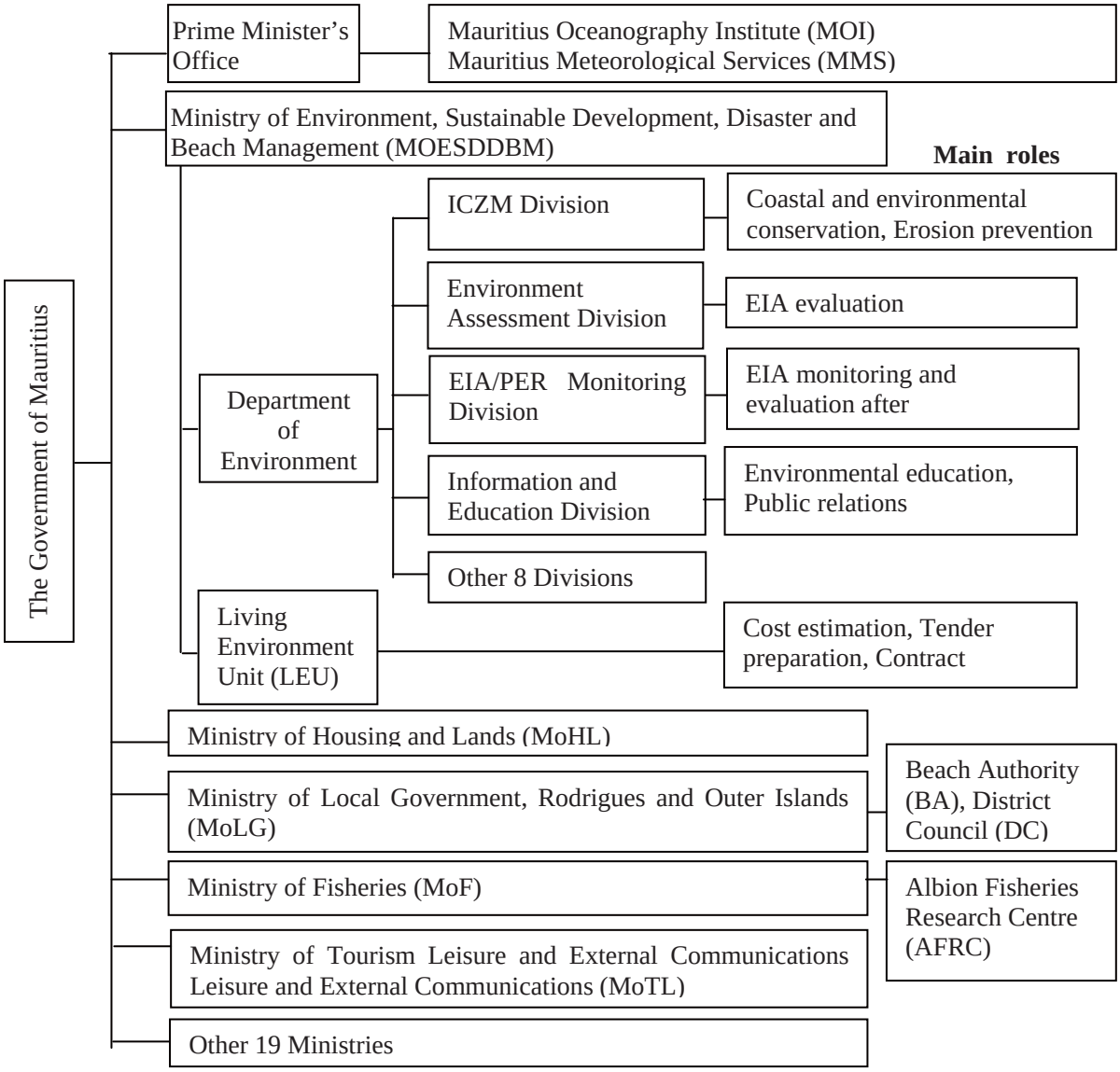
Step	Description	Standard of period
1st: Initial Check	Officer from the EIA Division of MOESDDBM verifies the required documents (PER and EIA)	Adequate number of days
2nd: Public scrutiny	The Director of MOESDDBM gives notice of public inspection in the Gazette and two newspapers.	Not exceeding 28 days
3rd: Observation or technical committee	The Director calls stakeholders to conduct the site visit and requires comments. Also the Director may request to set up a technical committee for advice.	No later than 42 days
4th: EIA committee examination	The Director reviews the EIA application and submits it to the EIA committee for examination and recommendations.	No later than 14 days
Final	The Minister, taking into consideration the recommendation of the EIA Committee, may approve the issue of an EIA license or reject the EIA application.	7days
Total		56-98days

Source: JICA Expert Team summarized “Development of an Integrated Coastal Zone Management Framework (ICZM) for the Republic of Mauritius, Landell Mills, 2009”

c. Organization

c.1 Organization Chart

The Government of Mauritius consists of 25 ministries. Among these, the ministries that are mainly related to ICZM are shown in the following figure. Since the organization structure was applied to prepare the capacity development plan in the Project, the structure is presented as of 2013.



Source: JICA Expert Team summarized "Development of an Integrated Coastal Zone Management Framework (ICZM) for the Republic of Mauritius, Landell Mills, 2009"

Figure 2.3.1 Government Organizations related to ICZM

c.2 Organization in Charge of Coastal Conservation

Based on the legal framework and organization structure in previous sections, roles and organizations in charge of coastal conservation are summarized as follows. The relationship in Table 2.3.14 is taken into consideration when planning the capacity development in this Project and it will be evaluated and reviewed through the demonstration project.

Table 2.3.14 Procedure of Coastal Conservation and Corresponding Roles and Organizations

Procedure	Details	Roles of the Government	Main organizations
Basic study	Beach profile and bathymetric survey	Implementation	BA, MoHL, MOI
	Coral reef and water quality survey	〃	MoF (AFRC)
	Wave and current measurement	〃	MoF (AFRC), MOESDDBM, MMS
Coastal conservation plan	Coastal protection plan	Preparation/ Evaluation	MOESDDBM
	Breach use plan	〃	BA, MOESDDBM, MoTL
	Land use plan	〃	MoHL, MOESDDBM
	Environment conservation plan	〃	MoF (AFRC), MOESDDBM
	Consensus building	Implementation	MOESDDBM
Design and construction	Basic design	Evaluation	MOESDDBM
	Detail design	〃	MOESDDBM
	Implantation plan	〃	MOESDDBM
	EIA	Approval and license	MOESDDBM (EIA Div.)
	Consensus building	Implementation	MOESDDBM, MoLG (DC)
	Tender and contract	Preparation of related documents	MOESDDBM (LEU)
	Construction	Management during construction	MOESDDBM
Management and maintenance	Maintenance of existing coastal structures	Implementation	MoLG (BA, DC), MOESDDBM
	Maintenance of public facilities	〃	MoLG (BA, DC), MOESDDBM
	Monitoring of beach profile and bathymetry*1	Implementation, evaluation and feedback to the plan	MoHL, MoLG (BA), MOI, MOESDDBM
	Monitoring of coral reef and water quality	〃	MoF (AFRC), MOESDDBM
	Management of land use	Review and permission for construction	MoLG (DC)
		Management after construction	(Not conducted)
	Management of beach use	Management of illegal activities	MoLG (BA)

*1 Lessee is responsible for leased area, *"MOESDDBM" without special note generally means ICZM Div. * 〃 : same as above", *DC: District Council, *BA: Beach Authority

Source: JICA Expert Team

2.4 Past Coastal Disasters and Countermeasures

Examples of events that had a significant impact so as to change the direction of coastal project policy in Mauritius were studied. Based on this study future mitigation measures were analyzed regarding to coastal conservation facilities.

2.4.1 Coastal Disasters

Wave height of typical cyclones that either directly made landfall or passed by Mauritius since 1960 are shown in Table 2.4.1 below. The table shows three underlined cyclones that will be investigated further to determine appropriate mitigation measures for coastal facilities in Mauritius.

Table 2.4.1 Typical Cyclones in Mauritius' Recent History

Cyclone	Maximum significant wave height(m)			
	N	S	E	W
1960-Carol	12.51	10.94	14.00	12.61
1989-Krisy	5.07	5.76	6.26	5.44
1994-Hollanda	10.66	12.94	13.51	10.49
1995-Ingrid	6.13	8.68	8.37	6.94
1996-Bonita	5.91	4.08	5.25	4.28
1996-Daniella	7.38	6.02	7.69	10.28
1996-Flossy	3.66	5.42	5.19	4.25
1998-Anacelle	7.45	9.63	9.90	8.11
1999-Davina	7.79	9.49	10.59	11.37
2000-Connie	8.67	12.29	12.94	8.72
2002-Dina	11.78	10.12	11.49	7.41
2002-Guillaume	8.67	12.29	12.94	8.72
2003-Gerry	8.92	8.60	10.44	6.71
2005-Hennie	5.40	5.67	6.17	4.78
2007-Gamede	5.22	3.53	4.53	4.37
2008-Hondo	2.90	2.17	2.86	2.40
2009-Gael	3.12	2.21	2.86	2.95
2010-Gelane	3.32	3.17	3.65	2.15
2012-Giovanna	5.13	3.69	4.84	3.81
2013-Dumile	2.52	2.06	2.37	2.98
2013-Imelda	3.19	2.83	3.31	2.20

Source: JICA Expert Team

a. Carol (1960)

Damage due to Cyclone Carol in 1960 such as over-topping and coastal erosion was a catalyst for changes to land use policy of coastal areas in Mauritius. Small-scale revetments were began to be built following this cyclone.

b. Hollanda (1994)

Cyclone Hollanda in 1994 caused damage to the areas around small structures that had been built since 1960 as well as beach scarps. In response, coastal protection measures such as gabions have been implemented by the government since 1996, and construction of has been applied for counter measures.

c. Dina (2002)

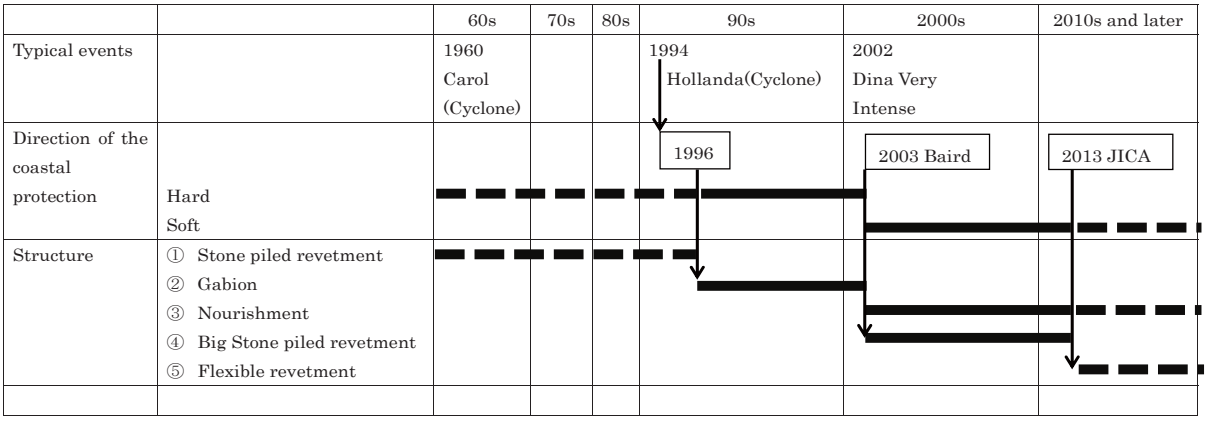
Cyclone Dina in 2002 is the largest cyclone in the past record. Due to the disastrous situation

after the cyclone, construction of rock revetments all along the coastal area in Mauritius has been applied based on the recommendations of the Baird Report in 2003. On the same period of time, beach nourishment also was applied as one of the mitigation measures for coastal conservation, which is considered to be a more flexible mitigation measure.

2.4.2 History of Coastal Structures

History of coastal structures and concept of coastal conservation in Mauritius are determined as per the table below illustrating characteristics of past underlined cyclones in periodical order.

Table 2.4.2 History of Coastal Structures in Mauritius



Source: JICA Expert Team

Since 1960 small-scale revetments have been built along the coast. The structures were designed for protection of land but were not designed with coastal structural concepts in mind, and were mostly built by individual lessees.

Gabions were built in the aftermath was applied for restoration of the disaster of Cyclone Hollanda in 1994 and it resulted in certain achievements with regard to the rehabilitation of revetments and eroded coasts in Mauritius. Policy of protecting coast by structures was clarified in this period of time.

In response to the need to recover from Cyclone Dina in 2002, the Baird Report was published in 2003. The report included two mitigation concepts. One was the protection of coastal area by rock revetments and the other was flexible mitigation measures mainly composed of nourishment consisting mainly of local materials.

Additionally, concept of more flexible mitigation measures was introduced by JICA based on studies in Mauritius underway since 2012 and flexible revetments have been adopted as a coastal mitigation option since 2013.

Coastal structures up to now can be divided into three categories, as below, regarding to its type and built period.

a) Structure built in or after1960: Small -scale structures

b) Structure built between 1994 and 2003: Gabions

c) Structures built between 2003 and 2013: Rock revetments (recommendation of Baird Report)

a. Structures built in or after1960: Small-scale structures

a.1 Revetment

A small-scale revetment is a retaining structure built of concrete or assembled rocks. Although it can be seen all over the country, it is not defined as a large structure with its height of approximately 2.0m at maximum.

a.2 Groyne

Small-scale groynes are constructed in Pte. d'Esny. Some of the groynes in the area are constructed in order to clarify boundary lines rather than focus on its function, although the others perform its own function. Under the guideline of government since 1996, some considerations have been made to avoid too much off shore sand movement with work to lower the crown height of the groynes.

b. Structures built between 1994 and 2003: Gabions

Gabions have been adopted in areas which need disaster recovery and emergency rehabilitation. Gabions are approximately 3.0m in height at the highest point. Some gabions are about twenty years old and in some cases the iron wires holding them together have been cut off due to rust.

c. Structures built between 2003 and 2013: Rock revetments

The structure consists of large rocks exceeding 1.0 ton in weigh and is a sloped revetment with a few meters in its height. A large number of rock revetments have been constructed based on the Baird Report since 2003. It was built in east coast of Mauritius in 2014 as well.

2.4.3 Previous Mitigation

a. Structures built in or after 1960: Small scaled structure

a.1 Revetment

Regarding to the situation in Riviere des Creoles, for example, progression of aging and deformation can be identified in some points of the revetment. In 2014 a flexible revetment was constructed based on the recommendations of Japanese engineers to alleviate a reported problem of crabs not being able to pass over the revetment (to lay eggs, etc.).

Source: JICA Expert Team

Figure 2.4.1 Revetment in Riviere des Creoles

a.2 Groyne

Small-scale groynes are constructed by lessees of coastal land in Pte. d'Esny. Structure of the groyne is composed of assembled rocks held together with mortar and with a width of 1.5m on the crest. Most of the groynes have a height of less than 1.0m, however, some are 3.0m high on the beach section as they also function to demarcate the property boundary line.

There are areas of coastline in Pte. d'Esny where groynes and partial coastal erosion are hindering beach accessibility and preventing people from walking along the beach. This is an issue with regards to coastal management and public coastal use.

Source: JICA Expert Team

Figure 2.4.2 Groyne in Pte. d'Esny

b. Structures built between 1994 and 2003: Gabions

Regarding to the gabion in Saint Felix, it was constructed between 1995 and 1996 after the cyclone hit in 1994. The height of the gabion is approximately 5.0m at the highest part. Cut off iron wires and scattering of rocks from within the gabion on the sandy beach were identified in the field in 2012.

Source: JICA Expert Team

Figure 2.4.3 Gabion in Saint Felix

c. Structures built between 2003 and 2013: Rock revetments

c.1 Pte. aux Sables

The rock revetment at Pte. aux Sables was built covering the existing beach to a height of over 2.0m. The revetment was constructed to prevent the erosion at the public beach and has proven to be effective. Furthermore, since it is a comparatively new structure and the weight of rocks is sufficient to protect them from being moved, no major problems have been identified so far. However, since the alignment of the revetment is set along the existing coastal line, it is possible it is blocking the sand movement along the shoreline (littoral drift) due to its covering the sand beach. In fact, there has been erosion on an adjacent section of coastline causing the destruction of a small-scale revetment that existed there. Accessibility to the beach from on top of the revetment is poor because the surface of the revetment crest is not comfortable to walk on as well as the width of sand beach is not wide enough.

Source: JICA Expert Team

Figure 2.4.4 Rock Revetment at Pte. aux Sables

c.2 South of Grand Sable

The rock revetment in the south of Grand Sable is smaller than the one at Pte. aux Sables in size and there is a pedestrian walkway along the top of it. However, base of the revetment is completely under sea water and tidal markings on the revetment slope reveal that the tide reaches half way up the revetment. It is difficult to access to the beach due to some slippery

surfaces on the slope of the revetment.

Source: JICA Expert Team

Figure 2.4.5 Rock Revetment in the South of Grand Sable

2.4.4 Issues of Coastal Protection Facilities in Mauritius

a. Ensuring Continuity

Coastal areas generally play a significant role as a transitional zone from land to sea. It is important to allow coastlines to be able to change gradually and continuously, and the setting of distinctive borders as well as unmovable objects can have significant negative impacts.

Several issues have been observed in the Riviere des Creoles area, such as obstructing the ability of crabs to crawl between the beach and the foreshore and changes to the vegetation. Additionally it is clear that the revetments in Sable and South Grand Sable are obstructing accessibility to coastal area.

Moreover, it is possible that the rock revetments are causing coastal erosion by decreasing the volume of sand movement in the area on the downstream side of the revetments.

Therefore, it is clear there are ecosystem, beach usage and sand movement issues when coastal protection structures such as those with stable borders impede the continuity of the coastal area.

b. Materials

It should be noted that special care is needed when constructing coastal structures using materials that do not naturally belong to the local coastline. And in Saint Felix, there is clear evidence to back up this statement as there is rusted metal and coarse rocks scattered around a gabion that was constructed with materials not naturally occurring on the coastline.

Additionally, boulders and rocks would blend into the surrounding landscape if they are of a moderate density, however when they form a large mass that is not proportion to the natural form of the coastline it is inappropriate from a landscape point of view. Therefore, it would be better to use materials which exist in the local coastal environment or to select suitable materials for the coastal environment in terms of preserving the natural landscape of the coastal area.

c. Cost

It seems that the materials of rocks are too big for coasts protected by a reef. Moreover, upon reviewing the design plans of the rock revetments, it was judged that the size of the rocks was three times larger than was necessary. Use of excessive materials means that the size as well as the cost of the coastal structures is excessive.

d. Application Method

As a coastal protection facility, it can be said that the applied types of structures, small-size revetments, gabions and rock revetments, are proven measures in general. However, as mentioned above, problems will arise when these measures do not meet the necessary requirements.

It seems the government applies new construction methods applied in other countries without any research about regional characteristic as well as problems to be solved. Applying the wrong mitigation methods would make the situation worse. Therefore, it would be better to consider the applicability of coastal protection facilities.

2.5 Coastal Characteristic and Modification Analysis

2.5.1 Long term modification of Coastline

a. Analysis of Coastal Condition by Aerial Photo

To understand the situation of coastal erosion in Mauritius, the analysis of beach transformation is conducted by topographic interpretation (shoreline interpretation) of aerial photos. Table 2.5.1 lists the collected aerial photos used for analysis.

Although the topographic interpretation had been conducted by Baird (2003) and so on at some parts of beaches in Mauritius, it didn't cover the whole coastal area. The analysis in this study aims to analyze it more widely and utilize the results for preparation of a coastal conservation plan. In addition, the results can be saved as updatable database and used for the management purpose through capacity development activities in the Project.

Table 2.5.1 Collected Aerial Photos to Analyze

No.	Year	Source
1	1967	Ministry of Housing & Lands
2	1975	Ministry of Housing & Lands
3	1991	Ministry of Housing & Lands
4	1997-1999	Ministry of Housing & Lands
5	2008	Ministry of Housing & Lands (Satellite Images)
6	2012	Google Earth

Source: JICA Expert Team

a.1 Summary

Table 2.5.2 Summary of the Situation of Coastal Erosion

Objective	To understand the situation of coastal erosion around Mauritius.
Method	Topographic interpretation (shoreline interpretation) of aerial photos with GIS
Results	・17% of beaches around Mauritius have been eroded in the long term, 59% are stable and 23% have been accreted. ・There are 18 sections whose erosion rate of shoreline changes in the long term is more than 0.2m/year. ・Average of the short-term fluctuations of shorelines is about 0.5m/year.
Consideration and Conclusion	Short-term fluctuation rate of shoreline is generally larger than long-term change. Such short-term fluctuations (erosion) are considered to be the result of cyclones.

Source: JICA Expert Team

a.2 Regions subject to Analysis

Sediment Cell No.1 – No.13 at 20 coastlines for basic survey are subject to this analysis of beach transformation. And each sediment cell was divided into sub cells separated at inflection points on the shoreline such as rocky points, river mouths and jetties.

The total number of sub cells is 105 (refer to Table 2.5.3). And the total length of shorelines is approximately 67 km. Figure 2.5.1 shows an example of region subject to analysis (around Pointe aux Sables in the west of Mauritius Island). Other regions subject to analysis are shown in Chapter 1 of Supporting Report.

Table 2.5.3 Regions Subject to Analysis

Sediment Cell No.	Sum of Sub Cells	Beach Name (Number in parentheses is sub cell No. corresponding to the beach)
1	4	Baie du Tombeau (1-4)
2	16	Pte. aux Cannoniers (1-4), Mon Choisy (5-7), Trou aux Biches (8-9), Pointe aux Piments (10-16)
3	6	Roches Noires (1-6)
4	5	Bras d'Eau (1-2), Part of P.G. Choisy (3-5)
5	16	Belle Mare (1-4), Palmar (5-10), Q. Cocos Vge (11-12), T. d'Eau Douce (13-16)
6	7	Île aux Cerfs (1-7)
7	8	Pointe d'Esny (1-4), Blue Bay (5-8)
8	7	Souillac (1-3), Saint Felix (4-7)
9	5	Bel Ombre (1-5)
10	7	P.G. Le Morne (1-5), Le Morne Brabant (6-7)
11	13	Flic en Flac (1-3), Wolmar (4-5) Tamarin (6-9), La Preneuse (10-13)

12	5	Albion (1-5)
13	6	Pointe aux Sables (1-6)
Total	105	

Source: JICA Expert Team

Source: JICA Expert Team

Figure 2.5.1 Example of a Region Subject to Analysis (Pointe aux Sables)

a.3 Analyzing Method

Shoreline was interpreted from aerial photos after the geometric corrections by GIS. And the area between the shoreline and fixed common baselines on the land side was measured for various dates using GIS. Advance and retreat (accretion and erosion) of the shoreline was calculated by dividing changes in area by the shoreline length.

Shoreline lengths in this analysis was defined using aerial photos taken in 2008 which had the highest resolution of those available. These lengths were fixed as the representative values in the Study.

Tidal levels at shoreline positions were not calibrated because there are only small differences in tidal level in Mauritius.

All of these works are able to be easily done with GIS. It is considered that C/P will continually update the database in case new aerial photos are obtained in future.

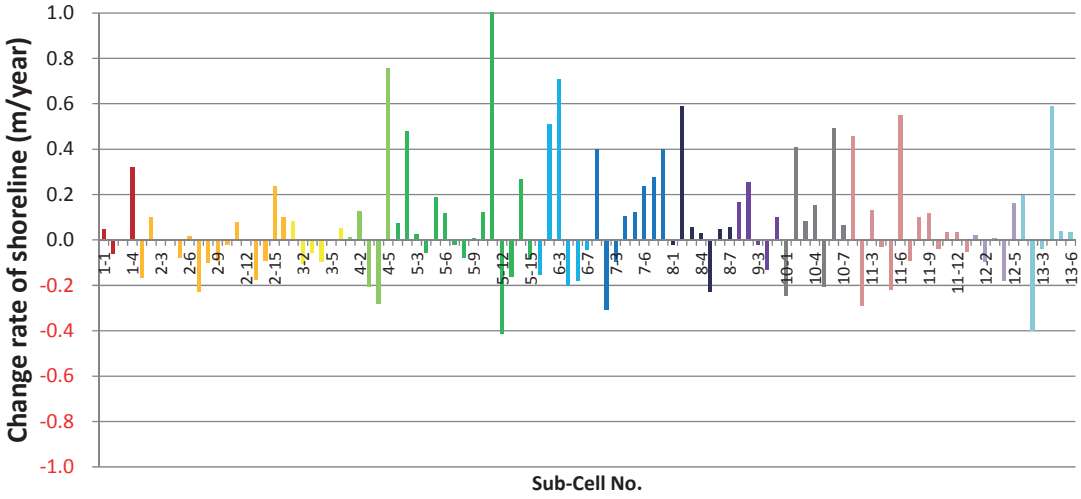
With changes of shorelines analyzed by above method, magnitude of long-term changes and fluctuations of shoreline were calculated. The former was defined as average change rate (m/year) for 45 years, namely 1967 to 2012. And the latter was defined as standard deviation of

change rates of five sequential short-term periods.

a.4 General Results of Analysis

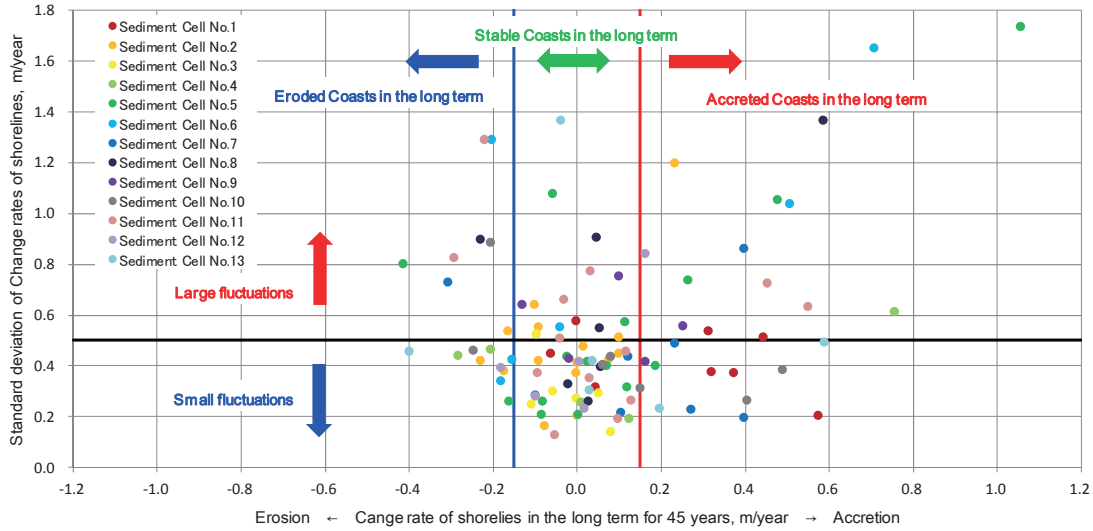
In this study, a stable coast is defined as a coast with shoreline changes of less than 10m for recent 50 years (±0.2m/year). Finally, it was defined as ±0.15m/year considering the accuracy of interpretation of aerial photos. With this definition, ratio of long-term accretion coast in Mauritius is 17%, stable coast is 59%, and eroded coast is 23%. That is to say there are many stable and accretion coasts in the long term, and eroded coasts are limited in Mauritius.

Average of standard deviations of change rates of the five sequential short-term periods in all coasts is approximate 0.5m/year. Therefore, the fluctuations are generally larger than the long-term changes. That is caused by beach transformation as a result of cyclones striking the coast.



Source: JICA Expert Team

Figure 2.5.2 Change Rates of Shorelines in Each Sub-Cell



Source: JICA Expert Team

Figure 2.5.3 Change Rate of Shorelines in the Long Term and Fluctuations of Change Rates in each Sub-Cell

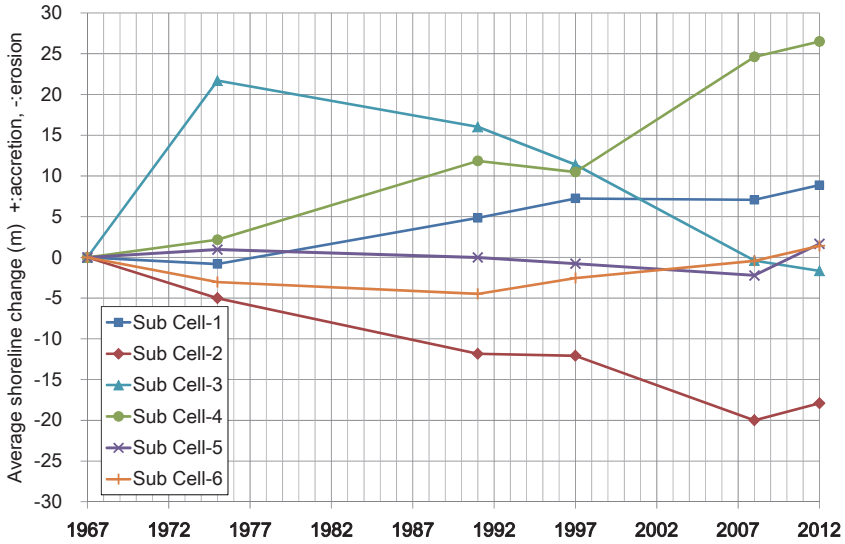
a.5 An example of specific beach transformation

Figure 2.5.4 shows spatial averages of shoreline changes since 1967 in six sections around Point aux Sables (Sediment Cell No.13). Other results are shown in the supporting report.

Figure 2.5.6 shows aerial photos and shorelines around Pointe aux Sables at three representative times (1967, 1991 and 2008). The shoreline of approximately 600m (Sub Cell-2) to the west of the rock revetment constructed in 2010 is showing an erosion trend, however the coastline fluctuation is relatively small. The shoreline of approximate 1 km to the east side of this revetment, Sub Cell-4, also has an apparent erosion trend, the fluctuation of which is equally small. It is supposed that the longshore sediment transport from Cell-2 to Cell-4 is dominant and the effect on temporary beach transformation by cyclones is small. Therefore, fluctuations of shoreline in this area are small.

In the area between both of the above the sub cells, namely Sub Cell-3, the sandy beach in front of the houses has now completely disappeared, as shown in Figure 2.5.5, so risk of overtopping waves is large. According to the results of analysis using past aerial photos, this area has long-term erosion trend after 1975, before the construction of rock revetment (2010). The possibility that sandy beach will recover naturally is low due to construction of the revetment, so conservation countermeasures for this area in addition to the long-term erosion area (Sub Cell-2) in the west side of the rock revetment are necessary.

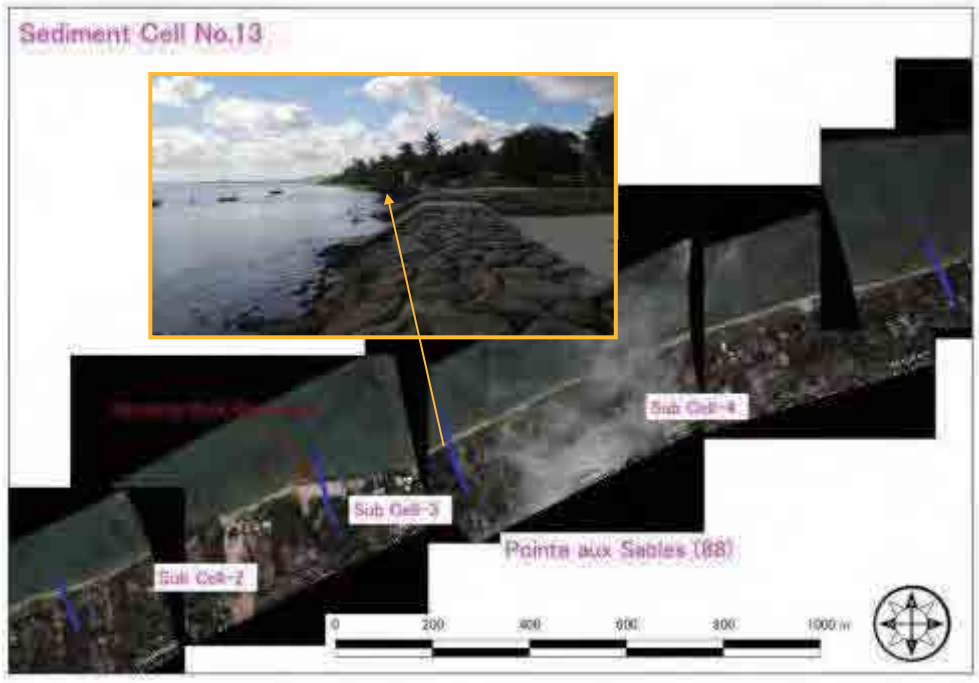
Table 2.5.4 lists the change rates and standard deviations in each coast. These values were rounded to one decimal place considering the accuracy of interpretation of aerial photos. Eighteen coasts in Mauritius show a long-term erosion trend with more than 0.2m/year of change ratio.



Source: JICA Expert Team

(Sediment Cell No.13: around Pointe aux Sables, refer to Figure 2.5.1)

Figure 2.5.4 Spatial Averages of Shoreline Changes since 1967



Source: JICA Expert Team

Figure 2.5.5 Actual Situation (2012) of around the Rock Revetment in Pointe aux Sables

1967	
1991	
2008	

Source: JICA Expert Team

Figure 2.5.6 Shoreline Changes around Pointe aux Sables

Table 2.5.4 Change Rates of Shorelines in the Long Term and Standard Deviations of Short-Term Change Rates

Unit: m/year

Sub Cell No.	Change Rate in the long term	S.D. of change rates	Beach Name	Sub Cell No.	Change rate in the long term	S.D. of change rates	Beach Name
1-1	0.0	0.3	Baie du Tombeau	7-1	0.4	0.9	Pointe d'Esny
1-2	-0.1	0.4	Baie du Tombeau	7-2	-0.3	0.7	Pointe d'Esny
1-3	0.0	0.6	Baie du Tombeau	7-3	-0.1	0.3	Pointe d'Esny
1-4	0.3	0.4	Baie du Tombeau	7-4	0.1	0.2	Pointe d'Esny
2-1	-0.2	0.5	Pte. aux Cannoniers	7-5	0.1	0.4	Blue Bay
2-2	0.1	0.5	Pte. aux Cannoniers	7-6	0.2	0.5	Blue Bay
2-3	0.0	0.2	Pte. aux Cannoniers	7-7	0.3	0.2	Blue Bay
2-4	0.0	0.4	Pte. aux Cannoniers	7-8	0.4	0.2	Blue Bay
2-5	-0.1	0.2	Mon Choisy	8-1	0.0	0.3	Souillac
2-6	0.0	0.5	Mon Choisy	8-2	0.6	1.4	Souillac
2-7	-0.2	0.4	Mon Choisy	8-3	0.1	0.5	Souillac
2-8	-0.1	0.6	Trou aux Biches	8-4	0.0	0.3	Saint Felix
2-9	-0.1	0.6	Trou aux Biches	8-5	-0.2	0.9	Saint Felix
2-10	0.0	-	Pointe aux Piments	8-6	0.0	0.9	Saint Felix
2-11	0.1	0.4	Pointe aux Piments	8-7	0.1	0.4	Saint Felix
2-12	0.0	0.4	Pointe aux Piments	9-1	0.2	0.4	Bel Ombre
2-13	-0.2	0.4	Pointe aux Piments	9-2	0.3	0.6	Bel Ombre
2-14	-0.1	0.4	Pointe aux Piments	9-3	0.0	0.4	Bel Ombre
2-15	0.2	1.2	Pointe aux Piments	9-4	-0.1	0.6	Bel Ombre
2-16	0.1	0.4	Pointe aux Piments	9-5	0.1	0.8	Bel Ombre
3-1	0.1	0.1	Roches Noires	10-1	-0.2	0.5	P.G. Le Morne
3-2	-0.1	0.2	Roches Noires	10-2	0.4	0.3	P.G. Le Morne
3-3	-0.1	0.3	Roches Noires	10-3	0.1	0.4	P.G. Le Morne
3-4	-0.1	0.5	Roches Noires	10-4	0.2	0.3	P.G. Le Morne
3-5	0.0	0.3	Roches Noires	10-5	-0.2	0.9	P.G. Le Morne
3-6	0.1	0.3	Roches Noires	10-6	0.5	0.4	Le Morne Brabant
4-1	0.0	0.3	Bras d'Eau	10-7	0.1	0.4	Le Morne Brabant
4-2	0.1	0.2	Bras d'Eau	11-1	0.5	0.7	Flic en Flac
4-3	-0.2	0.5	Part of P.G. Choisy	11-2	-0.3	0.8	Flic en Flac
4-4	-0.3	0.4	Part of P.G. Choisy	11-3	0.1	0.3	Flic en Flac
4-5	0.8	0.6	Part of P.G. Choisy	11-4	0.0	0.7	Wolmar
5-1	0.1	0.4	Belle Mare	11-5	-0.2	1.3	Wolmar
5-2	0.5	1.1	Belle Mare	11-6	0.6	0.6	Tamarin
5-3	0.0	0.4	Belle Mare	11-7	-0.1	0.4	Tamarin
5-4	-0.1	1.1	Belle Mare	11-8	0.1	0.2	Tamarin
5-5	0.2	0.4	Palmar	11-9	0.1	0.5	Tamarin
5-6	0.1	0.6	Palmar	11-10	0.0	0.5	La Preneuse
5-7	0.0	0.4	Palmar	11-11	0.0	0.8	La Preneuse
5-8	-0.1	0.3	Palmar	11-12	0.0	0.4	La Preneuse
5-9	0.0	0.2	Palmar	11-13	-0.1	0.1	La Preneuse
5-10	0.1	0.3	Palmar	12-1	0.0	0.2	Albion
5-11	1.1	1.7	Q. Cocos Vge	12-2	-0.1	0.3	Albion
5-12	-0.4	0.8	Q. Cocos Vge	12-3	0.0	0.4	Albion
5-13	-0.2	0.3	T. d'Eau Douce	12-4	-0.2	0.4	Albion
5-14	0.3	0.7	T. d'Eau Douce	12-5	0.2	0.8	Albion
5-15	-0.1	0.2	T. d'Eau Douce	13-1	0.2	0.2	Pointe aux Sables
6-1	-0.2	0.4	Île aux Cerfs	13-2	-0.4	0.5	Pointe aux Sables
6-2	0.5	1.0	Île aux Cerfs	13-3	0.0	1.4	Pointe aux Sables
6-3	0.7	1.6	Île aux Cerfs	13-4	0.6	0.5	Pointe aux Sables
6-5	-0.2	1.3	Île aux Cerfs	13-5	0.0	0.4	Pointe aux Sables
6-6	-0.2	0.3	Île aux Cerfs	13-6	0.0	0.3	Pointe aux Sables
6-7	0.0	0.5	Île aux Cerfs				

※Grey cells denote eroded beaches in the long term with more than 0.2m/year

Source: JICA Expert Team

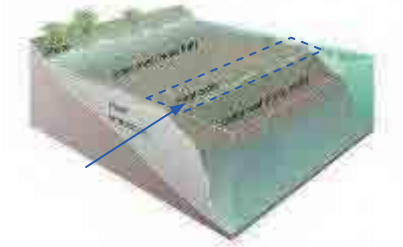
2.5.2 Coastal Sediment Budget

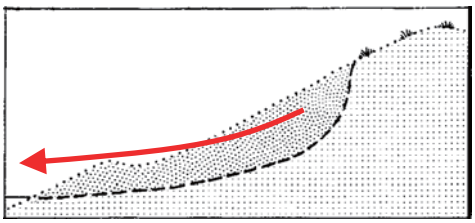
The transport volume of sediment was analyzed based on the situation of coastal erosion, which was understood as explained in the previous sections of this report. As a result in this section, for example, it is possible to estimate longshore sediment transport rate through the comparison of sediment budget between adjacent eroded and accreted areas. And the estimate contributes to studying the feasibility of countermeasures such as beach nourishment or sand recycling and planning required volumes for such measures. Moreover, it becomes possible to predict effect or influence of the construction of jetties, revetments and so on. The result will also be able to be updated by C/Ps in the future and that will help in developing their knowledge and capacity of integrated coastal management.

Before analysis, some phenomenon related to changes and fluctuations of sediment budget on the beach are shown below.

Table 2.5.5 Phenomena related to Changes and Fluctuations of Sediment Budget on the Beach

Phenomenon	Note	Fig.
Production of Coral Sand	Fragmented coral is produced by breaking waves around reef crest. After that, it is surged and becomes fine in the beach by waves or currents.	(1)
Sand transport by wave-induced current	Current in the coral lagoon is mainly induced by waves. We can recognize the current direction from the streak lines in aerial photos.	(3) (4)
Longshore Sediment Transport	Sediment transport along shoreline occurs in cases whereby waves strike the shoreline diagonally.	(3)
Cross-shore Sediment Transport	High waves wash out the beach and sediment flow out offshore. After the erosion, scarp is formed on the beach.	(2)
Outflow to Outside Reef	Wave-induced currents generally flow offshore through the reef gap and carry sediment to outside the reef.	(4)
Sediment Discharge from River Mouth	Sediment is supplied from river mouth with fresh water.	(4)
Coral Sand Mining	In the past, coral sand was mined all over Mauritius.	-





Source: JICA Expert Team

a. Summary

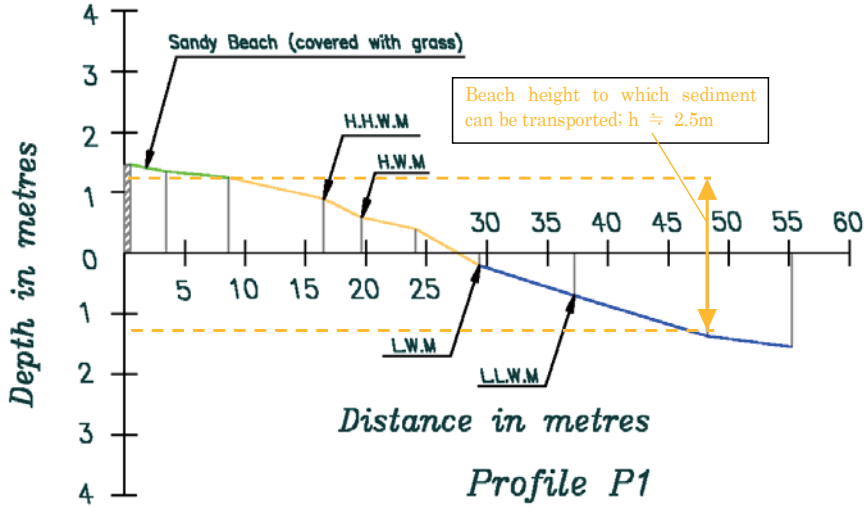
Table 2.5.6 Summary of Coastal Sediment Budget

Objectives	・ To estimate sediment transport rate through the coastal sediment budget analysis. ・ To examine influence of past coral sand mining on the coastal sediment budget. ・ To estimate contribution rate of coral sand production to coastal sediment budget. ・ To contribute to coastal conservation plan by developing basic data on beach nourishment, sand recycling and so on.
Method	Changes in sediment volume were estimated based on the aforementioned aerial photo interpretation, as well as on estimations of the height up the beach the littoral drift sediment is transported. Past studies were examined to estimate the volume of coral sand mining and production.
Results	・ Longshore sediment transport rate around Mauritius is about 1,500m3/year at most. ・ The influence of past coral sand mining to recent beach transformations is minor. ・ Coastal sediment budget has been generally increased in the long term and the increase corresponds with a quarter of coral sand production. ・ Some eroded sediments are transported outside of the reef.
Considerations and Conclusions	・ It is important to consider not only long-term erosion but also short-term beach transformation by cyclones. ・ It is possible to collect and utilize coral sand in the future in case that it is deposited in the wide lagoon in front of the beach. ・ Coral conservation is a significant component of coastal conservation plan. ・ It is possible to collect coral sand that has been transported offshore and recycle it for beach nourishment.

Source: JICA Expert Team

b. Analyzing Method

Volume of sediment transport was calculated by multiplying the change in coastal area (as outlined in the previous subsection) by the beach height. Beach height was estimated based on the available beach profile survey results. Figure 2.5.7 shows the result of beach profile survey in Pointe d'Esny. The moving height of the sediment was estimated to be 2.5 m based on the figure. In this analysis, beach height of 2.5 m was set for all regions since no significant differences among sites (sections) were found.



Source: This figure was processed by JICA Expert Team based on "W.F. BAIRD & ASSOCIATES COASTAL ENGINEERS LTD. (2003), Study on Coastal Erosion in Mauritius"

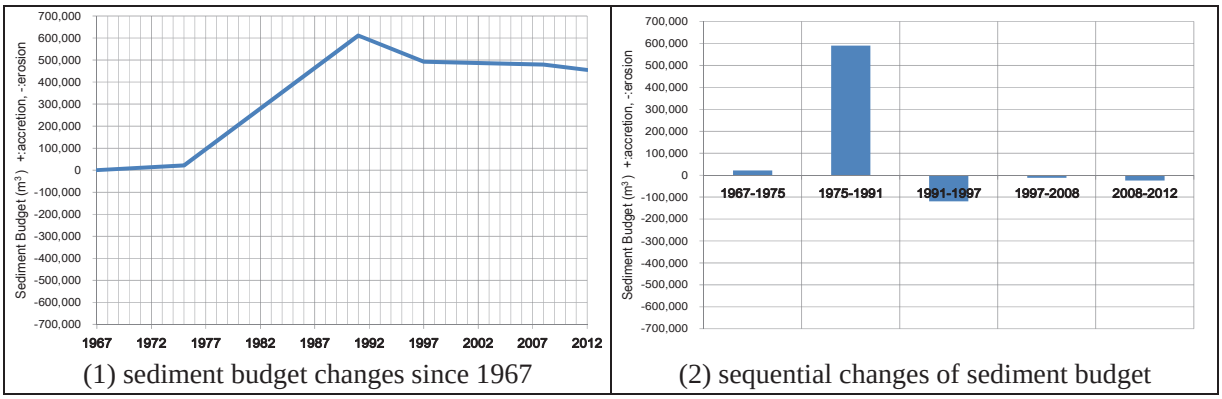
Figure 2.5.7 Beach Profile at Pointe d'Esny (Baird, 2003)

c. General Results of Analysis

Figure 2.5.8 shows sediment budget of analyzed coastline with total length of 67km. It has accretion trend in the long term. Especially, it is found that accretion in the period 1975 to 1991 was remarkable. However, erosion and accretion are balanced in recent years. It is supposed that accretion trend is due to production of coral sand. It will be verified in the following section of this report.

Figure 2.5.9 shows the frequency of occurrence for tropical cyclones in the vicinity of Mauritius. The relationship between the total sediment budget and the frequency is not clear. However, the frequency of occurrence for cyclones was relatively low from 1975 to 1991 when the accretion was remarkable. There is a possibility that there was a low level of sediment erosion caused by high wave induced cross-shore sediment transport in this period. And the frequency of cyclone occurrence was very high from 1991 to 1997 when erosion volume was relatively high.

It is important to consider not only long-term erosion but also short-term beach transformation caused by cyclones. When cyclone strikes a the coast, there is a possibility of wave overtopping disasters occurring caused by high waves and wave-setup. As a countermeasure against that, setback for dynamic beach changes is effective. Moreover, the beach profile can be significantly changed after a cyclone, as outlined in the following subsection *Previous Coastal Disasters*. The beach re-profiling is effective against such temporal beach transformations.

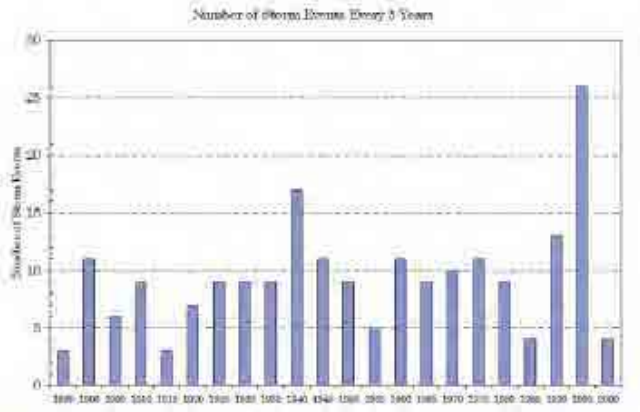


(1) sediment budget changes since 1967

(2) sequential changes of sediment budget

Source: JICA Expert Team

Figure 2.5.8 Sediment Budget for Total Analyzed Beaches



Source: Baird(2003)

Figure 2.5.9 Frequency of Occurrence for Tropical Cyclones in the Vicinity of Mauritius

d. Coral Sand Mining

In the past, since the beginning of 1900's, coral blocks and sand had been used for material of reclamation and refinement of lime for construction as well as refinement of sugar. Although coral and sand mining had been done all around Mauritius Island before 1970's, the activity of the mining had been permitted only in four sites on the eastern part after 1980. According to the AWAC (1993), sand mining had been mainly done at the sand bank of the area from north to east coast where large coral lagoon extends and the total extraction rate was about 500,000 tons / year (300,000 m^3/year) in 1993. However, coral sand mining was prohibited in 2000 (coral block mining was prohibited in 1980), and currently only limited coral sand mining is permitted.

When a lagoon is too wide wave dissipation is great and the fragmented coral (coral sand) is not transported to surge in the beach. It is considered that the generated coral sand deposits in the bank or pit of the lagoon. Although the influence of the past coral sand mining to recent beach transformation is minor, it is possible to collect and utilize coral sand in the future in case that it is deposited in the wide lagoon in front of the beach.

e. Production of Coral Sand

Although data on the sand production rate from coral reefs around Mauritius varies substantially in the literature, Montaggioni (1988) reports a figure of 4.5 kg/m^2/year. Moreover, the study in the Lagoon at La Prairie on the southwest of the Mauritius Island by SSPA Sweden AB (2003) used same unit generation load by the above-mentioned reference reports, and estimated 1500 tons (850m^3) in a year of sand production from a coral lagoon with a width of 37.5 m and a length of about 9 km. Furthermore, the study mentioned that the production rate is about 6 kg/m^2/year and total production in the area is about 2,000 tons (1,100m^3) / year in addition to the sand generation from calcareous algae and halimeda.

The study by Baird (2003) also assumed almost equal unit generation rate of 5 kg/m^2/year and estimated a sand production volume of 1,600 m^3/year (0.43-0.84 m^3/m/year) by analysing the sediment budget of a 3.2 km-long section of coast and coral lagoon at the north end of Flic en Flac. According to that report, it was also estimated that the sand production rate is 1.2-1.75 m^3/m/year at the coast of Belle Mare and 0.6-1.0 m^3/m/year at the coast of Palmar.

The total sand production over 45 years (1967 to 2012) for the total 67 km of sandy beaches where sediment budget has been analyzed in the Study was 1,800,000 m^3 ≒ 0.6 m^3/m/year×67,000 m×45 year. This calculation was based on an assumed sand production rate of 0.6 m^3/m/year using the above result in Flic en Flac as a reference. Then, it is found to be approximately four times as large as result shown in Figure 2.5.8, which was based on aerial photos interpretations. In other words, it is supposed that, on average, approximately a quarter of produced coral sand has been deposited on beaches in the long term; namely, that there is a long term accretion trend on beaches around Mauritius. Furthermore, by estimating total sand production for 16 years, coral sand production volume is approximate 640,000 m^3. It corresponds to the sediment budget result from 1975 to 1991 shown in Figure 2.5.8.

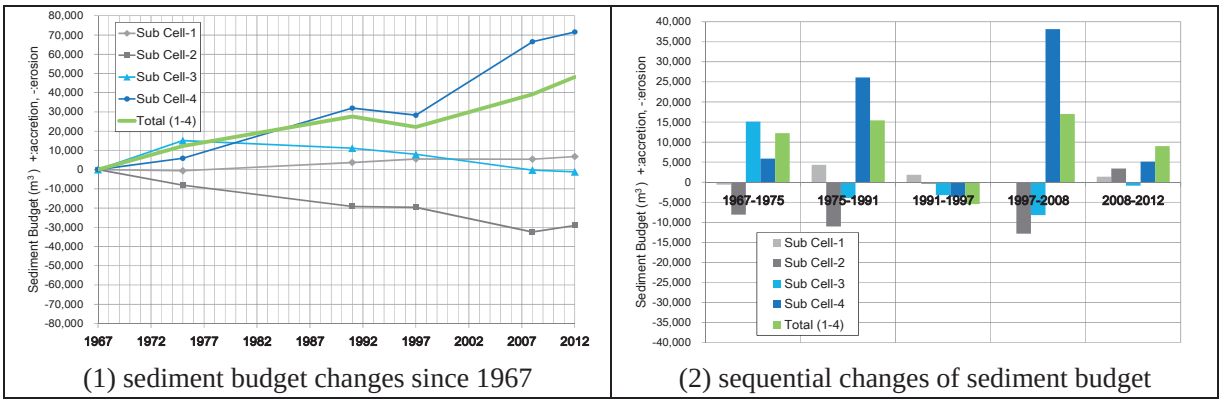
After the prohibition of coral sand mining, beaches around Mauritius generally have accretion trend. However, the number of living coral in front of some beaches is decreasing. Therefore, coral conservation is a significant component of coastal conservation plan.

f. An Example of Coastal Sediment Budget in Specific Beach

Figure 2.5.10 shows the results of specific coastal sediment budget estimations for Pointe aux Sables (refer to Figure 2.5.1). Erosion volume in Cell-2 doesn't completely balance with accretion volume in Cell-4, the accretion is superior to the erosion in total. It is considered that a reason for this is the supply of coral sand, as mentioned above in *e. Production of Coral Sand*. According to the average volume in erosion and accretion area, it is supposed that longshore sediment transport rate is approximately 1,100m^3/year in this area.

Table 2.5.7 lists the coasts where erosion and accretion by longshore sediment transport are shown by the coastal sediment budget analysis and rough estimates of those rates. Although longshore sediment transport rates largely depends on characteristics of topography and waves, it is about 1,500m^3/year at most.

Figure 2.5.11 shows an example of a beach, Albion, where erosion is thought to be caused by a mechanism besides longshore sediment transport. Cell-4 (12-4) in the south section of Albion has been eroded. It is considered that is caused by the disappearance of seagrass in front of the beach. Fluctuation of shoreline changes in the south edge of the coast Cell-5 (12-5) is large by the longshore sediment transport from an adjacent beach. It doesn't seem to be long-term erosion in that local section. However, the overall ("Total 1-5" in the figure) trend in the long term is of erosion. It suggested that seagrass and coral deterioration in the front lagoon has been causing this erosion. Other results in each sediment cell were shown in the supporting report.



(1) sediment budget changes since 1967

(2) sequential changes of sediment budget

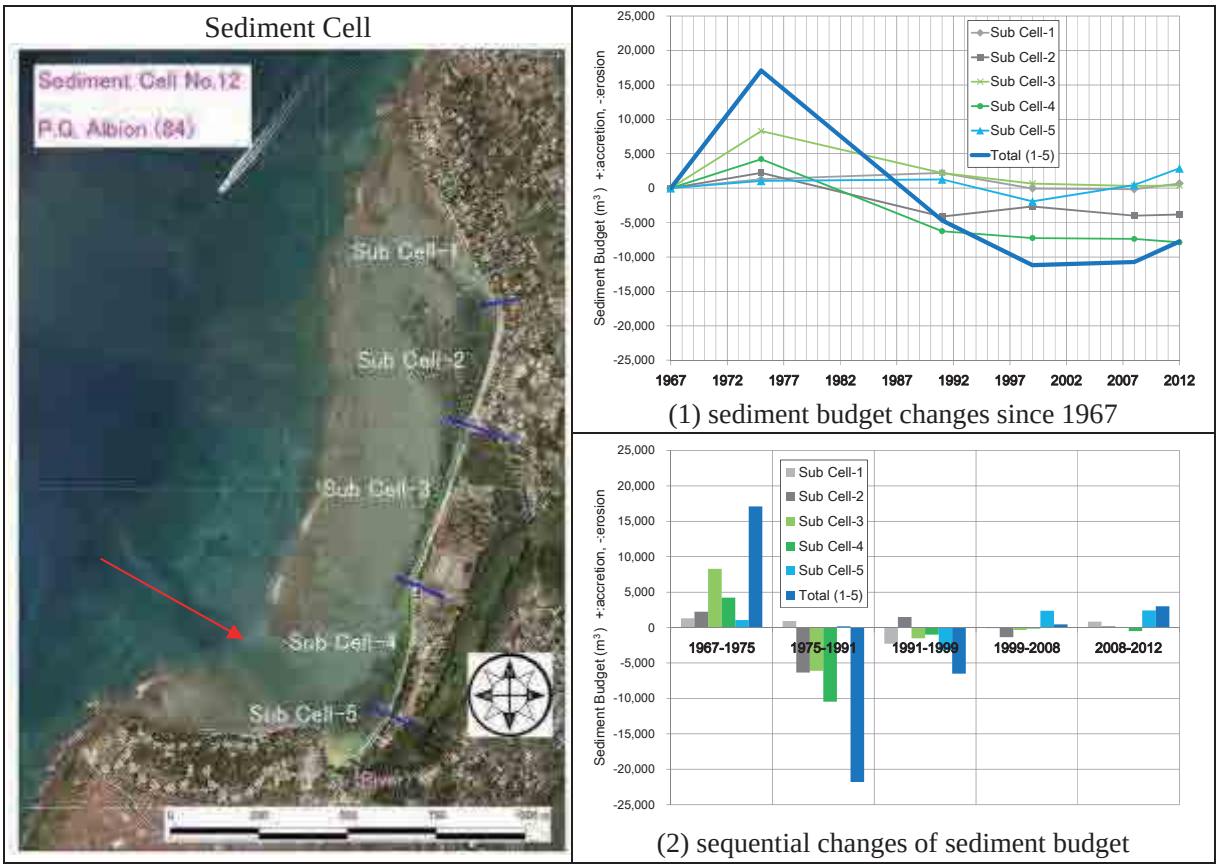
Source: JICA Expert Team

Figure 2.5.10 Coastal Sediment Budget in Pointe aux Sables

Table 2.5.7 Longshore Sediment Transport Rate by Sediment Budget Analysis

Beaches	Sub Cell and Direction of Longshore Sediment Transport	Rough Estimates of Longshore Sediment Transport Rate (m^3/year)
Part of P.G. Choisy	4-3 and 4-4 → 4-5	300
Palmar	5-7 and 5-8 → 5-9 and 5-10	150
Q. Cocos Vge	5-12 → 5-11	700
T. d'Eau Douce	5-13 → 5-14	200
T. d'Eau Douce	5-15 → 5-16	150
Pointe d'Esny	7-2 and 7-3 → 7-1	900
P.G. Le Morne	10-2 → 10-1	800
Flic en Flac	11-2 → 11-1	1,500
Pointe aux Sables	13-2 → 13-4	1,100

Source: JICA Expert Team



Source: JICA Expert Team

Figure 2.5.11 Sediment Budget in Albion

g. Sediment Outflow to Outside Reef

It is considered that eroded sediment in the south section of Albion, Cell-4 (12-4) as shown above has been transported to outside of the lagoon through the reef gap.

Baird (2003) has estimated that the sediment volume which has been transported to offshore sinks was 1,000-1,500m^3/year in the north section of Flic en Flac. Moreover, according to the bottom survey from the central to south of Flic en Flac by MOI (2010), it was found that 2,760m^3 of sand has been deposited at inner reef around reef gap (3m depth) and 12,240m^3 and 5,000m^3 of sand was deposited at another outer reef (13-17.5m depth). Sediment types were fine and coarse sand.

The study team in this project also found coarse sand (median diameter: about 0.5mm) at the outer reef in Le Morne and Trou aux Biches. This is considered evidence of the sediment outflow to outside reef through the reef gap. It is possible to mine coral sand offshore and recycle it for beach nourishment. Pertinent agencies are sharing this information through the technical committee, and another survey by MOI is being implemented now.

2.6 Coastal Environment

2.6.1 Water Quality Environment

Coral reefs, lagoons and the seashore are regarded as one system in Mauritius. Attempts are being made to protect the coast and monitor the state of the coral reefs and the water quality, but monitoring is fragmentary and inadequate. Therefore, the existing materials on water quality monitoring in Mauritius were collected to obtain the basic materials for grasping the present condition of water quality in each water area and for planning future water monitoring. Based on the results of existing surveys, the water quality survey to measure the concentration of nutrient salts in sea water, especially in the lagoons in Mauritius where coral reef degradation has recently become conspicuous, and a water quality survey was conducted in rivers and drainage canals that flow into the target lagoons to grasp the actual pollution loads.

a. Current State and Issues of Water Quality Monitoring in Mauritius

a.1 Water Quality in Mauritius Based on Existing Data

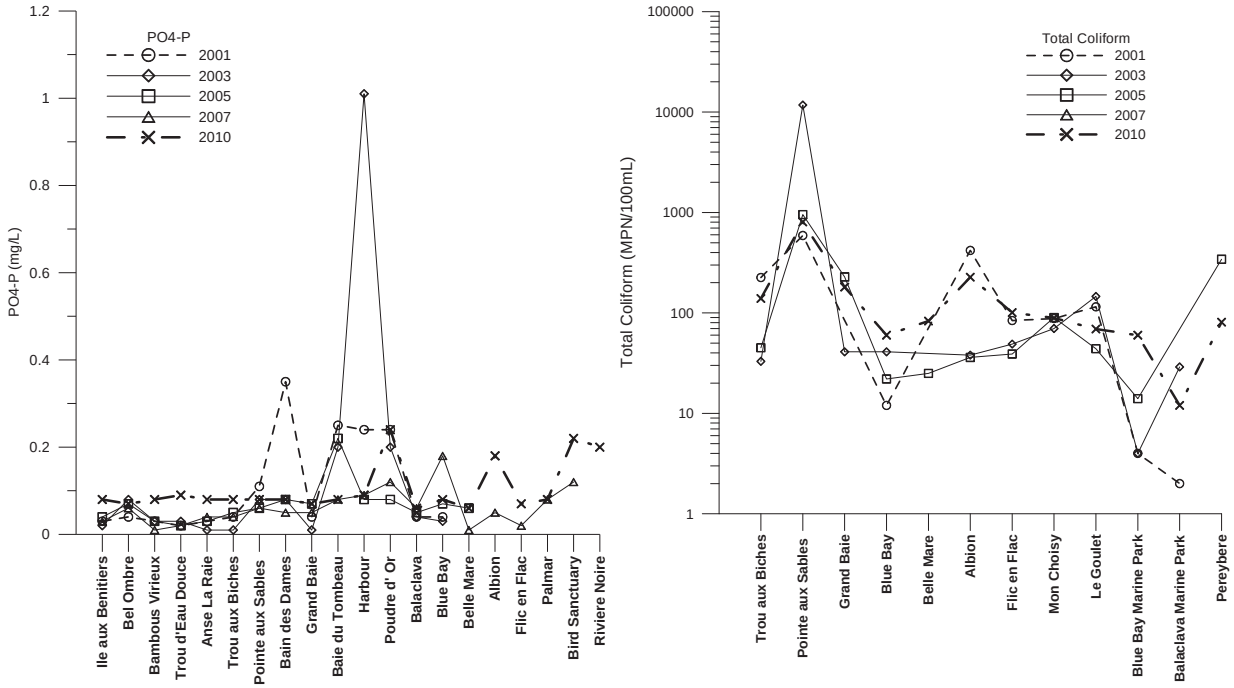
At present, four organizations monitor water quality in Mauritius. Coastal seawater in the lagoons is monitored by the Albion Fisheries Research Centre (AFRC), surface water (rivers, ponds, etc.) by the National Environmental Laboratory (NEL), treated wastewater by the Wastewater Management Authority (WMA) laboratory, and well water for drinking (drilling wells) by the Central Water Authority (CWA) laboratory.

The main water quality parameters in lagoons are nitrate and phosphate of nutrient salts, and chemical oxygen demand (COD), an indicator of organic contamination, together with coliform and fecal coliform. Figure 2.6.1 shows the AFRC monitoring points.

Source: AFRC

Figure 2.6.1 Locations of Water Quality monitoring in Lagoons by AFRC

Figure 2.6.2 shows the status of PO_4-P and total coliform from 2001 to 2010. The water quality values in the figure are the highest values for each year.



Source: These figures were prepared by JICA Expert Team, based on Annual Report from 2001 to 2010 by AFRC

Figure 2.6.2 Status of Water Quality in Lagoon by AFRC

As shown in the results mentioned above, heavily polluted water was found in the lagoons on the coasts of Bain des Dames, Baie du Tombeau, Harbour and Pointe aux Sables in the early part of the first decade of this century (from 2001 to 2003) and on the coasts of Pointe aux Sables, Albion, Bird Sanctuary and Riviere Noire since 2007, on the western coast of the island of Mauritius. The extremely large number of coliform bacteria found in the water of the lagoon at Pointe aux Sables, in particular, suggests increasing water pollution caused by the pollution load of domestic wastewater in the lagoon.

Meanwhile, heavily polluted water was found in the lagoon on the coast of Poudre d'Or in the early part of the first decade of this century and in the lagoons on the coasts of Poudre d'Or and Blue Bay since 2007, on the eastern coast of the island. In Poudre d'Or, in particular, because of the heavy water pollution caused by the wastewater from a textile plant in 2000, sludge in the coastal area was removed and a wastewater treatment plant was constructed. Since then, the water quality has gradually improved. However, as mentioned in another section (Coral Survey), coral coverage in the lagoon is 0 %. This fact suggests that water pollution by this plant has led to the drastic decline of corals in the lagoon.

a.2 Problems in Water Quality Monitoring in Mauritius

Table 2.6.1 is a summary of water quality monitoring (measuring frequency, measurement items) by the various organizations. Issues on water quality monitoring in Mauritius are addressed below:

- There are very few common parameters to grasp the overall water quality conditions in land and sea areas and the impact on coral reefs. To grasp the state of pollution of the sea area by the polluting load from the land area, it is basically necessary to monitor common parameters on both land and sea areas.

- There are few measurement items for nitrogen and phosphorus, which are important for assessing eutrophication of sea areas (only inorganic nitrogen NO_3-N is measured, while total nitrogen and total phosphorus are not measured. Therefore, there is no way of knowing the concentrations of these substances in the sea water (ratio of inorganic to organic, etc.) and it is impossible to judge whether the coral is going eutrophic. In addition to the existing monitoring items, inorganic NH_4-N, NO_2-N, total nitrogen and total phosphorus must be added to the monitoring items.

Generally speaking, coral reefs prefer oligotrophic environments with low concentration of nutrients. Therefore, to grasp the changes in the coral's habitat arising from man-made impacts, it is necessary to accurately measure the water quality of the sea area together with the nutrients. However, the accuracy of nutrient analysis (nitrogen, phosphorus) carried out by current water quality monitoring of the sea area is low, and low level nutrient concentrations cannot be grasped. Therefore, the accuracy of nutrient analysis must be improved.

Table 2.6.1 Implementation Status of Water Quality monitoring in Mauritius

Parameters	**Coastal Water by AFRC**	**River Water by NEL**	**Treated Wastewater by WMA**	**Borehole Water by CWA)**
	Quartery	Annually	1-2 Monthly	2 Yearly
Temperature	○	○	○	
pH	○	○	○	○
Salinity/ConDuctivity	○	○	○	○
DO	○	○		
COD	○		○	○
BOD			○	
NO3-N	○	○	○	○
NO2-N		○	○	○
NH4-N			○	○
K-N		○		
T-N				
PO4-P/ Reactive P	○		○	○
T-P				
Total coliform(TC)	○	○	○	
Feacal coliform(FC)	○		○	
E. Coli		○		
SO4		○		○
Mg		○		
Na		○		
K		○		
TSS			○	
TDS		○		
Oil & Grease			○	

Source: Report [Independent Environment Audit on Wastewater Projects (2010～2011)]

b. Water Quality Survey Conducted in the Project

The survey focused on chlorophyll a, nitrogen and phosphorus, the indicators of eutrophication and health of the coral reefs proposed in the research mentioned above, to grasp their concentration levels in seawater, especially in the lagoons in Mauritius where coral reef degradation has recently become conspicuous, and to explore the relationship between coral reef degradation and eutrophication. A water quality survey was conducted in rivers and drainage canals that flow into the target lagoons to grasp the actual pollution loads.

Table 2.6.2 Summary of Water Quality Environment

Objective	In order to obtain the basic materials on the plans for coastal protection and coral reef conservation, the present status of water quality, the future water quality monitoring plan and the water quality factors which influence on deterioration of coral reefs were studied.
Methodology	The water quality survey to measure the concentration of nutrient salts in sea water, especially in the lagoons in Mauritius where coral reef degradation has recently become conspicuous, and a water quality survey in rivers and drainage canals that flow into the target lagoons were conducted as well as the collection of existing materials on water quality monitoring.
Results	• The accuracy of nutrient analysis (nitrogen, phosphorus) carried out by current water quality monitoring of the sea area is low, and it is difficult to grasp the eutrophication conditions in lagoons adequately. • The concentration of nitrogen in lagoons is several to ten times higher than in rivers and that of phosphorus is the same. • The coral coverage decreases as the increase of turbidity, the concentration of chlorophyll a, nitrogen (NO_3-N) and phosphorus (PO_4-P). • Coral is being deteriorated at lower concentrations of nutrient loading than those outlined in the Mauritius water quality guidelines for coral conservation.
Discussion/ Conclusion	• Coral reefs prefer oligotrophic environments with low concentrations of nutrients. Therefore, to grasp the changes in the coral's habitat arising from man-made impacts, it is necessary to accurately measure the water quality of the sea, including the abovementioned nutrient concentrations. • The rehabilitation of the corals in the lagoons will require a reduction in the concentration of: chlorophyll a, turbidity, nitrogen, and phosphorus. Especially, reducing the concentration of chlorophyll is vital as a measure against eutrophication of lagoons.

Source: JICA Expert Team

b.1 Locations of Water Quality Survey

From the perspective of coastal preservation, and targeting those lagoons for which existing monitoring data has been accumulated and which have a reef with a sandy beach and a coastline with the potential for future tourist development, a water quality survey is conducted in the following representative lagoons with different types of eutrophication where coral reef degradation has recently become conspicuous.

1. Pointe aux Sables
2. Albion
3. Le Morne/ Ile aux Benitiers
4. Bel Ombre
5. Blue Bay

6. Ile de I'Est and Ile aux Cerfs
7. Trou d'Eau Douce
8. Bell Mare/ Palmar

Three lateral lines are established in each lagoon to grasp the water quality of the whole lagoon, and three or four points are established on the shore, in the middle of the lagoon and around the edge of the reef to grasp the water quality in the longitudinal direction from the shore reef to the back reef.

b.2 Survey Method

Lagoon

It was conducted from high tide, when the effects of rivers and drainage are more apparent in the sea area, to low tide, to grasp the spread of pollution from the land area to the lagoon. The water quality of the whole wide area was grasped mainly by simple water quality meter (multi-item water quality meter) and the water quality in the middle of the lagoon is analyzed by sampling. Allowing for seasonal changes in the waves (wind and waves due to the southeast trade winds, surges from the southwest, cyclone waves (December – March)) and seasonal changes (rainy season and dry season) in rainfall (river outflow), the survey would be conducted twice a year.

[Field Measurement by Portable Water Quality Meter]

Water temperature, Salinity, Turbidity, chlorophyll a, Dissolved Oxygen (DO), pH

[Water Quality Analysis by Laboratory]

T-N*, NO_3-N, NO_2-N*, NH_4-N*, T-P*, PO_4-P, chlorophyll-a*

*: These parameters are not monitored in Mauritius at present.

River and Discharge

In the water quality survey of the rivers and discharges flowing into the lagoons, with the exception of Pointe aux Sables, the impact of drainage canals (small rivers and discharges) is thought to be greater than the impact of large rivers. The following rivers and drainage canals were surveyed.

1. Small rivers in Bel Ombre
2. Riviere Noir
3. Small rivers in Albion
4. GRNW

[Field Measurement]

Width of river, Average depth, River current, Water temperature, Salinity, Turbidity, Dissolved Oxygen (DO), pH

[Water Quality Analysis by Laboratory]

T-N*, NO_3-N, NO_2-N*, NH_4-N*, T-P*, PO_4-P

*: These parameters are not monitored in Mauritius at present.

b.3 Water Quality Survey Results

The relationship between the water quality and the condition of the corals and the sources of the pollutants in lagoons are summarized as follows:

- The water quality survey shows that the coral coverage decreases exponentially with the increase of the turbidity, and the concentration of chlorophyll a, nitrogen (NO_3-N) and phosphorus (PO_4-P).

- The relation between the coral coverage and the concentration of each parameter was derived from the correlation between each as shown in Table 2.6.3. It is necessary to decrease the chlorophyll a to under 0.2μg/L, the turbidity to under 1-2 NTU, NO_3-N to under 0.012mg/L, PO_4-P to under 0.007mg/L in order to maintain the coral in a healthy condition similar to that of 1998 when the coral condition was assumed to be good.

- It becomes clear that the coral was degraded at nutrient concentration levels lower than those stipulated in the Mauritius water quality guidelines for coral conservation, namely class A1 (NO_3-N: 0.2mg/L, PO_4-P: 0.04mg/L). It is necessary to revise the guidelines, to add new monitoring parameters such as chlorophyll a and turbidity and to conduct highly accurate water quality analysis of nitrogen and phosphorus.

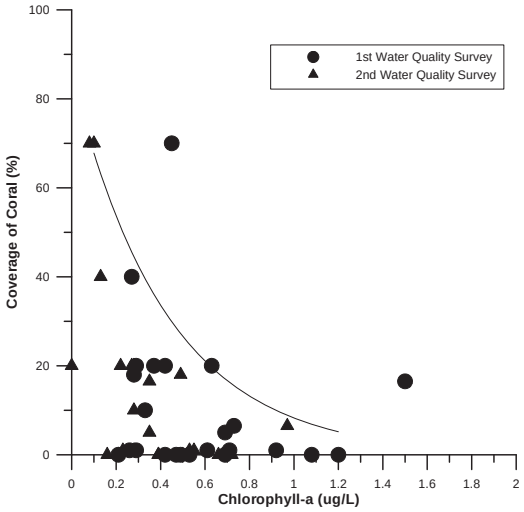
- The chlorophyll a is a kind of index to show the volume of the phytoplankton and the progress of eutrophication if the concentration is high. The coasts where there is a high concentration of chlorophyll a are the populated coasts such as Pte. aux Sables, Baie du Tombeau and the coasts behind in dense farmland such as Mon Choisy, Pte. aux Cannoniers, Bell Mare and Palmar in the survey. The eutrophication seems to be caused by the wastewater from houses and tourist facilities and by the outflow of fertilizer.

Therefore, the conservation of corals in the lagoons will require a reduction in the turbidity, and the concentration of chlorophyll a, nitrogen and phosphorus. Especially the reduction in the concentration of chlorophyll a requires the reduction of inflows of nitrogen and phosphorus loads from the hinterland.

Table 2.6.3 Relation between Coral Coverage and Water Quality

Coverage of live corals	Chlorophyll-a (ug/L)	Turbidity (NTU)	NO_3-N (mg/L)	PO_4-P (mg/L)
>50%	**<0.2**	**<0.5**	**<0.012**	**<0.007**
20-50%	0.2-0.6	0.5-1.36	0.012-0.051	0.007-0.016
10-20%	0.6-0.9	1.3-1.9	0.051-0.081	0.016-0.023
<10%	>0.9	>1.9	>0.081	>0.023

Source: JICA Expert Team



Source: JICA Expert Team

Figure 2.6.3 Relation between Chlorophyll a and Coverage of Coral

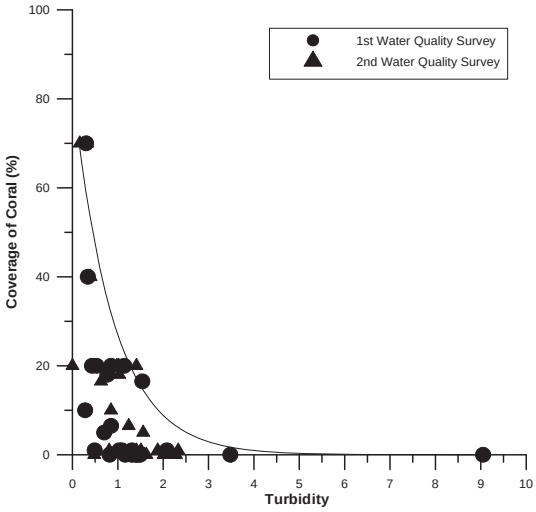
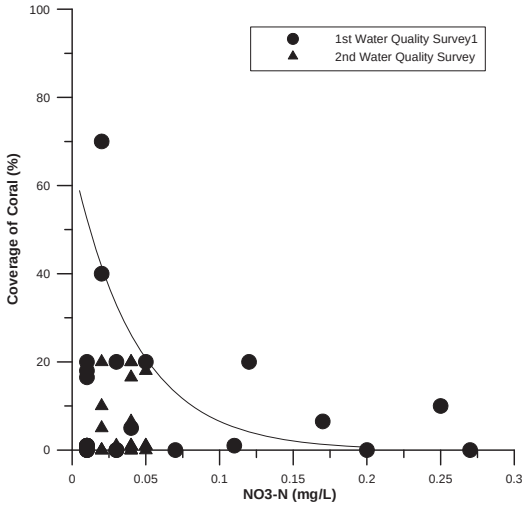


Figure 2.6.4 Relation between turbidity and Coverage of Coral



Source: JICA Expert Team

Figure 2.6.5 Relation between NO_3-N and Coverage of Coral

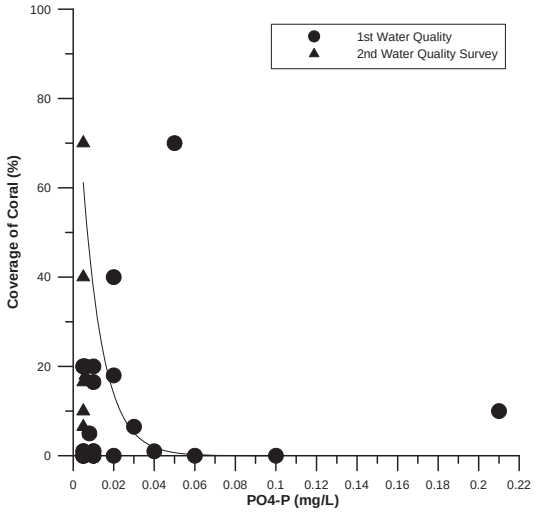


Figure 2.6.6 Relation between PO_4-P and Coverage of Coral

2.6.2 Coral Environment

Numerous unicellular symbiotic algae (zooxanthellae) dwell symbiotically in the body of reef building corals. Corals supply nutrients to symbiotic zooxanthellae and zooxanthellae give the photosynthetic products to the host coral, i.e. they have a symbiotic relationship. Because of this relationship, both organisms are alive in warm oligotrophic waters. Therefore, their habitats must be clear and shallow waters with sufficient sunlight for effective synthetic activity.

This monitoring survey was carried out within a short-term for obtaining the present condition and for understanding the problems in the Mauritian coral reefs from the viewpoint of their needs. Another purpose is a technology transfer to the counterparts (C/P) of Ministry of Environment and Sustainable Development (MOESDDBM) on methods and analysis of

monitoring during this monitoring survey.

Table 2.6.4 Results and Summary of the Survey on Coral Environment

Objective	Understanding the present conditions and problems, Technology transfer
Method	Monitoring survey by the spot-check method (Japanese Ministry of Environment (2004)
Results	・ Coverage of live corals was only 27.2 % on average of 44 sites. This value was categorized as "bad condition" by a valuation basis. ・ Coral coverage has positive relationship with transparency, while negative with siltation. ・ According to the long-term survey by Albion Fisheries Research Center (AFRC), average coverage decreased from 51.4 % in 2000 to 19.2 % in 2010.
Discussion & Conclusion	・ Menaces to coral reefs in lagoon are as follows: coral bleaching events, eutrophication, siltation and fishing activity. ・ These seemed to be caused by long-term human activities.

Source: JICA Expert Team

a. Monitoring survey on present condition of coral reefs by spot-check method

a.1 Method

Monitoring surveys were carried out at 50 sites of Mauritian coral reefs in June and October, 2012, and February 2013 using the spot-check method (hereafter SC method) as part of the "Monitoring Site 1000 Project" by the Japanese Ministry of Environment (2004). SC method has been implemented from 2004 for "Monitoring Site 1000 Project".

Survey items are bottom condition, depth, coverage of live corals, life-form of dominant corals, density of juvenile corals (only genus *Acropora* and only less than 5 cm in diameter), maximum diameter of 5 tabular type corals, number of *Acanthaster planci*, number of predacious snails and number of fish longer than 30 cm during 15 minutes swimming.

Other items such as transparency, deposit condition of silt on the bottom (siltation) and coverage of macro-algae were also recorded. Because SC method is normally carried out using snorkeling, the observers do not require a diving license of SCUBA.

In this survey, we did not use the diving boat as a rule and so we mainly carried out the survey by beach entry from the public beach. All public beaches are registered and given a number by the Ministry of Environment, Sustainable Development, Disaster and Beach Management (MOESDDBM). Monitoring sites were selected and decided after discussion with the officers of MOESDDBM as counterpart (C/P) on the basis of the information from scientific officers of Mauritius Oceanography Institute (MOI) and Albion Fisheries Research Center (AFRC). At first, selected sites were 55, but monitoring was carried out at 50 sites because of the strong winds by a cyclone. We went to the public beaches and measured the latitude and longitude at each beach by mobile GPS. After bringing back the temporary GPS data, we obtained the exact latitude and longitude of the observed sea area using Google Earth.

a.2 Abstract of the results

Monitoring surveys on the present condition of coral reefs in the lagoons (both shoals and

deeper sections) were carried out at 50 sites of Mauritian coral reefs in June and October 2012, and February 2013 using the SC method. Six sites out of 50 sites were seagrass beds and 44 sites were partly covered by live corals or coral fragments.

Coverage of live corals at 44 sites except for 6 seagrass beds was only 27.2 % on average. The valuation basis of SC method is as follows:

- coverage of 80 % or over is excellent;
- coverage of 50 % or over and less than 80% is good;
- coverage of 30 % or over and less than 50 % is slightly bad;
- coverage of 10 % or over and less than 30 % is bad;
- and coverage less than 10 % is evaluated very bad.

So, coverage of 27 % in Mauritian coral reef is evaluated as “bad” according to SC method.

Table 2.6.5, Table 2.6.6 and Table 2.6.7 show the monitoring sites with latitude and longitude carried out in June, October in 2012, and February in 2013. And, these results are shown in Table 2.6.8, Table 2.6.9 and Table 2.6.10. Sites written with red letters in the tables show the coasts of “Physical measures in the demonstration project”, “Non-physical measures in demonstration Project” and “Continuous monitoring sites” (7 sites in total).

On the coverage of live corals, the sites 50 % or over in coverage were 14 out of 44 sites. Three sites surveyed in June were 50 % or over. Two sites, i.e. Cap Malheureux (No. 20) and Butte a l’Herbe (No.23) were 50 % and 70 % respectively because huge colonies of Galaxea fascicularis covered the bottoms. While, the site in T. d’Eau Douce (Shore reef) (No. 46) was also set on the huge colonies of Pavona spp., so the coverage was 90 % (Table 2.6.8). The numbers attached after the name of the sites were the register number by MOESDDBM.

In October, seven sites, i.e. Petit Verger (No. 87), Baie du Tombeau (No number), Trou aux Biches (No. 12), Pointe du Diable (No. 49), two sites at Belle Mare (Nos. 39, 49) and Ile aux Aigrettes (No number), were 50 % or over in coverage of live corals (Table 2.6.9). In Baie du Tombeau (No number), *Porites* spp. and branching-type *Acropora* were dominant in shore reef. Observation site in Pointe du Diable (No. 49) was located at shore reef and many kinds of corals were observed with *Porites* spp. and *Pocillopora damicornis.* Species diversity was very rich in spite of shore reef. In the other five sites, branching *Acropora* was dominant on sandy or pebble bottoms.

Tabular type coral, *Acropora cytherea*, was also abundant with branching *Acropora* ten years ago, but most of the colonies are dead and have become skeletons except for Ile aux Aigrettes (no number exists). Features of the sites with these coral communities were narrow reef, sufficient transparency, low siltation and swift current except for Petit Verger (No. 87). In two sites at Belle Mare (Nos. 39, 40), branching *Acropora* dominated and occupied 60 % in coverage, but transparencies were low and green filamentous algae covered the branching *Acropora*, which had partly died (Table 2.6.9).

Table 2.6.5 Monitoring Sites with Latitude and Longitude in June 2012

No.*	Name of Beach	Latitude	Longitude	Observed day	Remarks
19	Bain Boeuf	19° 59'00.51"S	57° 36'15.60"E	12-Jun	
20	Cap Malhaeureux	19° 59'05.94"S	57° 37'25.03"E	12-Jun	
27	Grand Gaube	19° 59'41.82"S	57° 39'10.61"E	13-Jun	
29	Poudre d'Or	20° 00'41.73"S	57° 41'05.17"E	13-Jun	No observation
45	T. d'Eau Daue (Le Tropical Hotel)	20° 14'11.12"S	57° 48'16.64"E	19-Jun	
47	GRSE	20° 17'36.56"S	57° 47'10.92"E	19-Jun	
	Baie du Cap Public Beach (close 71)	20° 30'07.45"S	57° 23'44.37"E	14-Jun	
72	P. G. L'Embrazure/ Le Morne	20° 28'06.51"S	57° 20'26.22"E	14-Jun	Seagrass bed
57	Blue Bay 1	20° 26'39.12"S	57° 42'44.52"E	15-Jun	
	Blue Bay 2	20° 26'39.85"S	57° 42'37.16"E	15-Jun	
67	Saint Felix	20° 30'35.47"S	57° 27'52.31"E	18-Jun	
70	Bel Ombre	20° 30'22.55"S	57° 24'05.05"E	18-Jun	Seagrass bed
77	La Prenause	20° 21'21.18"S	57° 21'33.39"E	11-Jun	
84	P. G. Albion (Shore reef)	20° 12'41.92"S	57° 24'06.05"E	11-Jun	
	P. G. Albion (Back reef)	20° 12'44.44"S	57° 24'00.39"E	11-Jun	
82	Flic en Flac	20° 16'41.98"S	57° 21'54.05"E	17-Jun	
46	Trou d'Eau Douce (patch reef)	20° 14'37.02"S	57° 47'54.05"E	20-Jun	Boat
46	Trou d'Eau Douce (shore reef)	20° 14'22.93"S	57° 47'39.82"E	20-Jun	Boat
	Ile aux Benitiers	20° 24'17.40"S	57° 24'04.20"E	21-Jun	Boat

* No. is followed by the decreared public beaches of Mauritius.

Source: JICA Expert Team

Table 2.6.6 Monitoring Sites with Latitude and Longitude in October 2012

No.*	Name of Beach	Latitude	Longitude	Conducted day	Remarks
78	Tamarin	20° 19' 35.13"S	57° 22' 22.39"E	1-Oct	
79	Wolmar	20° 18' 24.48"S	57° 21' 45.77"E	1-Oct	
	Ile aux Cerfs			2-Oct	Too rough
87	Petit Verger	20° 10' 20.53"S	57° 26' 17.85"E	5-Oct	
89	Pointe aux Sables (near Fisheies Post)	20° 09' 42.63"S	57° 28' 01.89"E	5-Oct	
	Baie du Tombeau	20° 06' 31.46"S	57° 30' 35.68"E	3-Oct	
1	Le Goulet	20° 06' 10.66"S	57° 30' 50.52"E	3-Oct	
4	Pointe aux Piments (Le Meridien Hotel)	20° 02' 03.85"S	57° 32' 30.18"E	4-Oct	
12	Trou aux Biches (in front of Police st.)	20° 04' 18.10"S	57° 30' 45.11"E	4-Oct	
75	P. G. Le Morne (near Barjaya Hotel)	20° 27' 01.46"S	57° 18' 29.77"E	8-Oct	
66	Riambel	20° 31' 17.92"S	57° 30' 32.77"E	8-Oct	Seagrass
49	Pointe du Diable	20° 20' 10.77"S	57° 46' 53.55"E	9-Oct	
50	Pointe des Bambous	20° 20' 53.54"S	57° 46' 05.84"E	9-Oct	
22	Anse La Raie	19° 59' 20.26"S	57° 38' 15.93"E	10-Oct	Algal bed
25	Belle Vue Cugnet	19° 59' 58.58"S	57° 39' 22.85"E	10-Oct	No survey
33	Poste Lafayette	20° 07' 49.30"S	57° 45' 26.44"E	12-Oct	
35	Poste Lafayette	20° 08' 32.89"S	57° 44' 49.63"E.	12-Oct	Seagrass
39	Belle Mare (nr Rsidence Hotel)	20° 11' 39.31"S	57° 46' 39.79"E	11-Oct	
40	Belle Mare (nr R. Thalasse Hotel)	20° 12' 02.51"S	57° 47' 15.02"E	11-Oct	
	Ile aux Aigrettes	20° 24' 49.80"S	57° 43' 37.62"E	15-Oct	Boat

* No. is followed by the decreared public beaches of Mauritius.

Source: JICA Expert Team

Table 2.6.7 Monitoring Sites with Latitude and Longitude in February 2013

No.*	Name of Beach	Latitude	Longitude	Sheduled day	Remarks
	Ple. D'Esny (Moat)	20° 26' 28.24"S	57° 43' 28.54"E	Feb. 15	
	Ple. D'Esny (Back reef)	20° 26' 47.81"S	57° 43' 13.90"E	Feb. 15	
	Blue Bay Entrance	20° 26' 53.11"S	57° 42' 52.86"E	Feb. 15	
	Close to No.71	20° 29' 11.35"S	57° 21' 10.91"E	Feb. 19	
14	Mon Choisy	20° 00' 57.18"S	57° 33' 22.19"E	Feb. 20	Seagrass bed
15	The Vale	20° 00' 07.75"S	57° 24' 10.09"E	Feb. 20	
44	Q. Cocos	20° 14' 03.50"S	57° 48' 22.68"E	Feb. 21	
	South of Q. Cocos	20° 14' 19.12"S	57° 48' 11.22"E	Feb. 21	Rock reef
	Ile aux Cerfs	20° 15' 5212"S	57° 48' 21.34"E	Feb. 22	Seagrass bed
	Ile aux Cerfs (Rock reef)	20° 15' 50.18"S	57° 48' 25.89"E	Feb. 22	Rock reef
48	Grand Sable	20° 19' 13.35"S	57° 46' 18.02"E	Feb. 25	
	Ile aux Aigrettes (South)	20° 25' 46.87"S	57° 44' 12.55"E	Feb. 27	
	Ile aux Aigrettes (North)	20° 24' 47.70"S	57° 43' 35.53"E	Feb. 27	

* No. is followed by the decreared public beaches of Mauritius.

Source: JICA Expert Team

Four sites were over 50 % in coverage when the survey was carried out in February 2013. These sites were Pte. d'Esny (back reef), Blue Bay Entrance and two sites around Ile aux Aigrettes. Tabular and branching-type *Acropora* were dominant in these four sites. These four sites lie at the southeast coast of Mauritius and are close to each other. Such coral communities were observed in many sites around Mauritius before 2000, but large-scale coral communities are now restricted to these four areas of sea (Table 2.6.10). Because of swift current, transparency is generally good and siltation is very low in this area of sea.

On the contrary, the sites less than 1 % in coverage were observed in five sites in June, i.e. sites of low coverage occupied about one-third of the total. Poudre d'Or (No. 29) is one of them. This site had low transparency (less than 1m) and heavy siltation because of strong easterly wind on the monitoring day. Visual observation was limited only in shallower area than 1 m and many fragments of macro-algae covered the bottom, so accurate coverage was not obtained. In GRSE (No. 47), transparency was also low and siltation was high. Coverage of macro-alga, *Sargassum*, was dense on the rocks in muddy bottom and live coral was rare on the rocky reef. Many skeletons of branching and tabular *Acropora* were observed in the site at La preneuse (No. 77) close to resort hotels. And, these skeletons were covered by macro-algae, genus *Padina*. Many fragments of massive *Porites* and branching *Acropora* were found in the site at T. d'Eau Douce (patch reef) (No.46), but only macro-algae and soft corals are scattered at present. Transparency was 5 m and siltation was low. Ile aux Benitiers (no number) was a typical back reef with many branching and tabular-type *Acropora* until ten years ago, but only a few colonies of *Millepora* dwell around the site at present. And, the fragments of branching and tabular-type *Acropora* were covered by macro-algae, genus *Padina*.

Monitoring sites less than 1 % of coverage were only four in October. Branching and tabular-type *Acropora* seemed to be dominant in Wolmar (No. 79) at one time, but now many kinds of macro-algae such as *Sargassum* are abundant on the fragments of skeleton. The site at Pointe aux Sables (No. 89) is a patch reef in the offshore of Fisheries Post and is located in the lagoon neighboring the port of Port Louis. Because the site is close to the port, transparency is low and siltation is high. Numerous fragments of branching *Acropora* were piled up in the monitoring site, but live corals are quite few at present. The site at P.G. Le Morne (No. 75) is facing to the south west coast of Mauritius. Transparency is good and there is no siltation. These conditions seem to be good as habitat of coral, but the live corals are very few. In the

lagoon, many fragments of branching type corals and various kinds of macro-algae are growing up on the fragments. Around the site at Anse La Raie (No.22), coral community seems to have developed formerly in the area at 1 km off the coastline, but live corals are few on the rocky shore except for patches of *Thalassodendron* and *Sargassum* at present.

Table 2.6.8 Results of the Survey in June 2012

No.*	Name of Beach	Types of bottom	Depth(m)	Coverage (%)	Transparency (m)	Juvenile corals	Siltation
19	Bain Boeuf	sand	1 – 2 m	30%	3 m	0 / m²	high
20	Cap Malhaeureux	sand, patch reef	1 – 3 m	50%	2 m	0 / m²	high
27	Grand Gaube	sand, patch reef	1 – 2 m	70%	less than 2 m	0 / m²	high
29	Poudre d'Or	sand & mud	0.5 – 3 m	0%	less than 1 m	?	very high
45	T. d'Eau Dauce (Le Tropical Hotel)	coral cobble	1 – 3 m	10%	3 m	0 / m²	high
47	GRSE	mud	1 – 2 m	0%	2 m	0 / m²	high
	Baie du Cap Public Beach (close 71)	sand	0.5 – 2 m	30%	10 m	0 / m²	low
72	P. G. L'Embrazure/ Le Morne	Seagrass	0.5 – 3 m	less than 1 %	5 m	0 / m²	middle
57	Blue Bay 1	sand	1 – 3 m	10%	10m	0 / m²	middle
57	Blue Bay 2	sand	1 – 4 m	20%	20m	0 / m²	middle
67	Saint Felix	sand	1 – 2 m	30%	5 m	0 / m²	middle
70	Bel Ombre	Seagrass	1 – 2 m	0%	5 m	0 / m²	low
77	La Prenause	sand, c cobble	0.5 – 1.5 m	less than 1 %	2.5 m	0 / m²	high
84	P. G. Albion Shore reef	coral cobble	less than 1 m	2%	3 m	0.1	low
84	P. G. Albion Back reef	coral cobble	1 m	33%	3 m	0 / m²	low
82	Flic en Flac	sand	1 – 2 m	30%	5 m	0 / m²	low
46	Trou d'Douce (patch reef)	coral cobble	1 – 3 m	less than 1 %	5 m	0 / m²	low
46	Trou d'Douce (shore reef)	patch reef	1 – 3 m	90%	5 m	0 / m²	low
	Ile aux Benitiers	sand	1 – 2 m	less than 1 %	5 m	0 / m²	middle

* No. is followed by the decreared public beaches of Mauritius.
Green shade means seagrass bed.

Source: JICA Expert Team

Table 2.6.9 Results of the Survey in October 2012

No.*	Name of Beach	Types of bottom	Depth(m)	Coverage (%)	Transparency (m)	Juvenile corals	Siltation
78	Tamarin	Shore reef	1 – 3 m	15%	8 m	0.7 / m²	No
79	Wolmar	Back reef	1 m	1%	8 m	0 / m²	No
87	Petit Verger	Moat, sand	1 m	60%	3 m	0 / m²	High
89	Pointe aux Sables (near Fisheies Post)	Coral cobble	1 – 2 m	1%	3 m	0 / m²	High
	Baie du Tombeau	Shore reef	1 – 3 m	60%	10 m	0 / m²	Low
1	Le Goulet	Shore reef	1 – 2 m	15%	1.5 m	0 / m²	Very high
4	Pointe aux Piments (Le Meridien Hotel)	Back reef	1 – 2 m	10%	5 m	0 / m²	Middle
12	Trou aux Biches (in front of Police st.)	Back reef	1 m	60%	10 m	0 / m²	No
75	P. G. Le Morne (near Barjaya Hotel)	Back reef	1 m	0%	15 m	0 / m²	No
66	Riambel	Seagrass	1 m	0%	10 m	0 / m²	No
49	Pointe du Diable	Shore reef	1 – 3 m	60%	5 m	0 / m²	Low
50	Pointe des Bambous	Shore reef	1 – 2 m	30%	10 m	0.1 / m²	Low
22	Anse La Raie	Moat, sand	1 – 2 m	0%	2 m	0 / m²	Middle
33	Poste Lafayette	Back reef	1 – 3 m	30%	20 m	0.8 / m²	No
35	Poste Lafayette	Seagrass	1 m	0%	2 m	0 / m²	Low
39	Belle Mare (nr Rsidence Hotel)	Moat, sand	1 – 2 m	60%	5 m	0 / m²	Low
40	Belle Mare (nr R. Thalasse Hotel)	Moat, sand	1 – 2 m	60%	10 m	0.1 / m²	Low
	Ile aux Aigrettes	Moat, sand	1 – 2 m	50%	25 m	0	No

* No. is followed by the decreared public beaches of Mauritius.
Green shade means seagrass bed.

Source: JICA Expert Team

Table 2.6.10 Results of the Survey in February 2013

No.*	Name of Beach	Types of bottom	Depth(m)	Coverage (%)	Transparency (m)	Juvenile corals	Siltation
	Pte. D'Esny (Moat)	Sand	1–2 m	1%	10 m	0/m²	No
	Pte. D'Esny (Back reef)	Back reef	1–2 m	70%	15 m	1.1/m²	No
	Blue Bay Entrance	Patch reef	1–3 m	40%	15 m	0/m²	No
	Close to No.71	Shore reef	1m	50%	15 m	0.3/m²	No
14	Mon Choisy	Seagrass bed	1–2 m	0%	1 m	0/m²	High
15	The Vale	Shore reef	1–3 m	1%	3 m	0.1/m²	Low
44	Q. Cocos	Patch reef	2 m	10%	10 m	0/m²	No
	South of Q. Cocos	Shore reef	2 m	0%	5 m	0/m²	Low
	Ile aux Cerfs	Seagrass bed	0.5–1 m	0%	3 m	0/m²	Middle
	Ile aux Cerfs (Rock reef)	Rock reef	1–2 m	5%	3 m	0.5/m²	Middle
48	Grand Sable	Sand/ Mud	1–2 m	0%	1m	0/m²	Very high
	Ile aux Aigrettes (South)	Patch reef/Sand	1–2 m	60%	20 m	0/m²	No
	Ile aux Aigrettes (North)	Patch reef/Sand	1 m	70%	20 m	0/m²	No

* No. is followed by the decreared public beaches of Mauritius.
Green shade means seagrass bed.

Source: JICA Expert Team

Two sites out of 13 sites were seagrass beds in the survey carried out in February 2013. Four sites out of the sites except for these two seagrass beds were less than 1 % (in coverage of live corals). They are Pte. d'Esny (Moat), The Vale, South of Q. Cocos Veg and Grand Sable. In Pte. d'Esny (lagoon), transparency was relatively good, but colonies of branching *Acropora* were scattered. Coral reef is not well developed in The Vale and waves are directly breaking on the shore. The seagrass, *Syringodium isoetifolium*, and macro-algae, genus *Sargassum*, covered shore reef, and live corals were rare. In South of Q. Cocos Veg located at a small cape, many macro-algae, genus *Padina*, covered the rock reef and live corals were quite rare. Transparency was very bad and siltation was also very high in the offshore of Grand Sable. Offshore bottom was covered by black mud and sand.

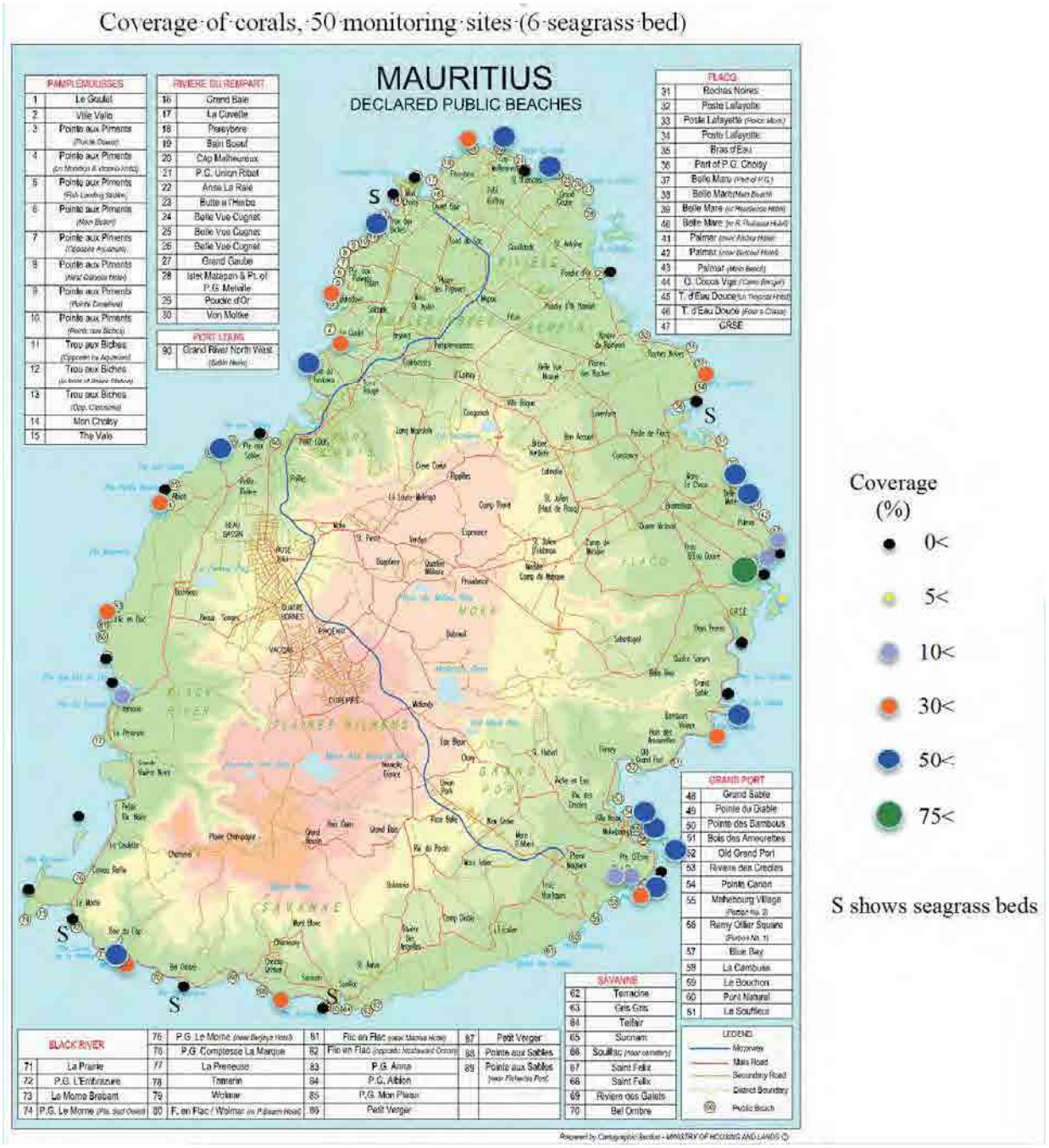
Among "Physical measures in the demonstration Project (Grand Sable)", "Non-physical measures in the demonstration project (Pte. d'Esny)", and five "Continuous monitoring sites", i.e. Mon Choisy, Ile aux Cerfs, Flic en Flac, Albion and Pointe aux Sables, except for Pte. d'Esny (back reef), Flic en Flac and Albion (back reef), the coverage of live corals was less than 5 %.

Figure 2.6.7 shows the coverage of live corals at 50 monitoring sites. Six sites out of 50 sites were seagrass beds and are attached "s". Sites of 50 % or over in coverage were generally located from NW – N – E – SE of the island. Sites from SW to S were low in coverage of corals. As described above, the site from Ile aux Aigrette to the entrance of Blue Bay is the only area of large-scale coral community of branching and tabular-type *Acropora*.

Transparency (m) at the monitoring survey is shown in Figure 2.6.8. Transparency is normally over 30 m in healthy coral reef. But, it slightly decreases within a coral reef lagoon. Sites over 10 m are 18 out of 50 sites and only one-third of the total. At Sekisei Lagoon coral reefs in Japan, sites of transparency over 10 m were observed at 97 % of the monitoring sites. Taking this fact into consideration, transparency in the Mauritian lagoon seems to be quite low.

Figure 2.6.9 shows five ranks of the siltation on the reef. Deposition of silt on the live corals causes suffocation of corals and decrease of photosynthetic activity by zooxanthella. Corals secrete mucus to remove silt, but such methods to remove are different in each species. Some species are not skillful at removing silt. Normally, there is no siltation in the healthy coral reefs.

Sites with no siltation were only 14 out of 50 sites, while the sites with heavy siltation (high or very high) were 12 out of 50 sites. So, Mauritian coral reefs are under very hard conditions for live corals from the viewpoint of siltation.

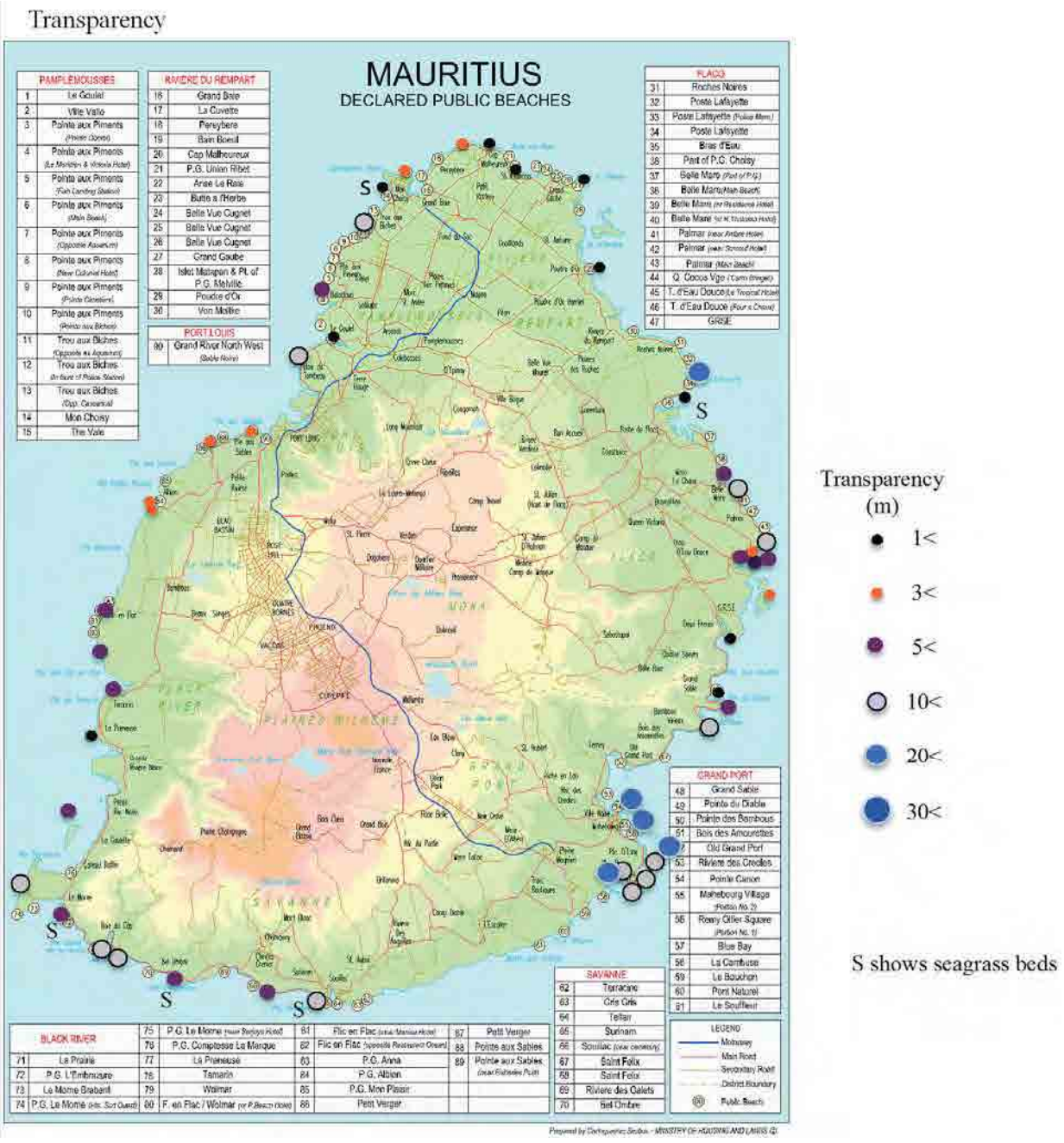


Source: JICA Expert Team

Figure 2.6.7 Distribution Map of Coral Coverage (%)

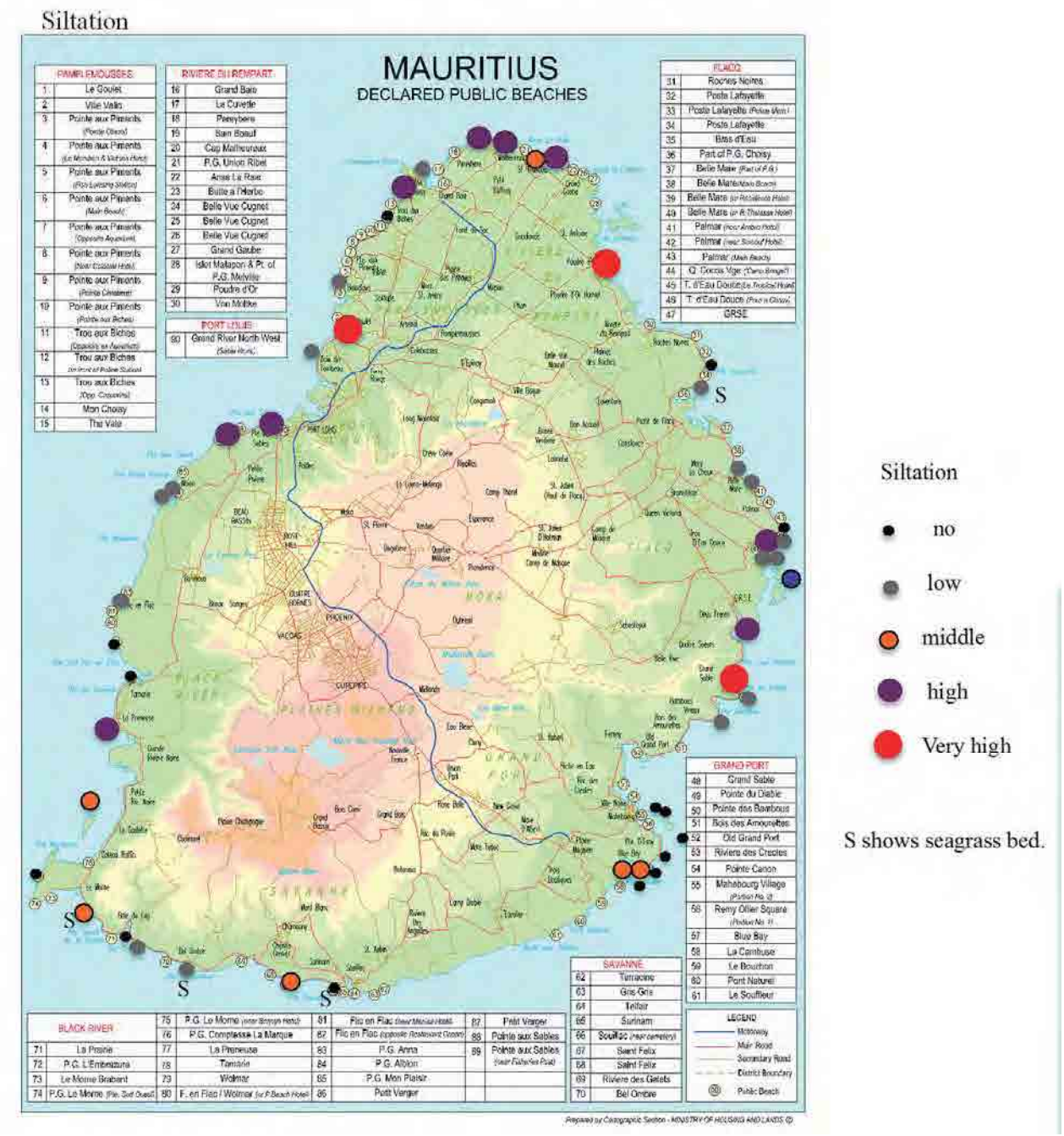
Figure 2.6.7 shows the relationship between coverage of live corals (%) and transparency (m). Red points in the figure show the coral community tolerant to muddiness, so these points are removed from consideration. The other coral communities are mainly dominated by branching and tabular-type *Acropora* which were dominant in Mauritian lagoons before 2000. Except for Petit Verger, the positive relationship is seen between coral coverage and transparency. Namely, coverage of live corals is higher in clear water conditions.

As mentioned above, deposition of silt is rare in healthy coral reefs. Figure 2.6.9 shows the relationship between coral coverage and rank of siltation. As shown in Figure 2.6.9, red points show the coral community tolerant to muddiness, so these points are removed from consideration. The other coral communities are mainly dominated by branching and tabular-type *Acropora*. Except for Petit Verger, coral coverage is higher in the sites with lower siltation, i.e. this fact suggests that deposition of silt is harmful influence on the live corals.



Source: JICA Expert Team

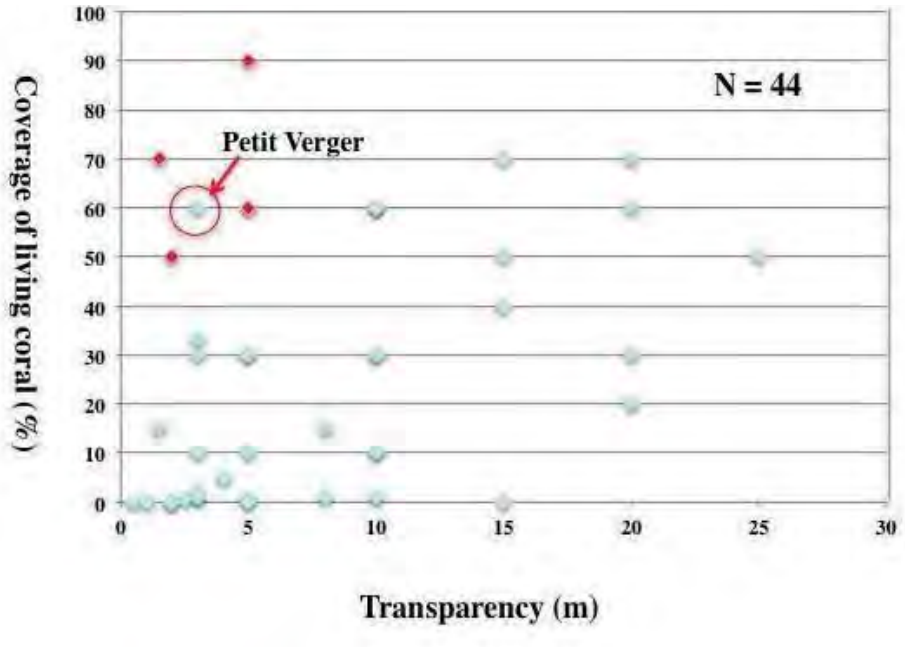
Figure 2.6.8 Distribution Map of Transparency (m)



Source: JICA Expert Team

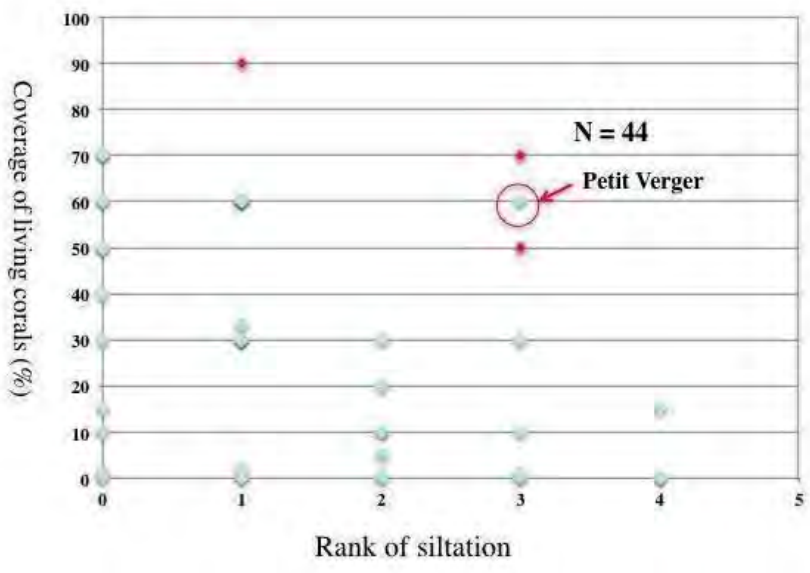
Figure 2.6.9 Distribution Map of Siltation

In this basic survey, technology transfer is another purpose. The initial purpose seems to be achieved through these monitoring surveys. SC method adopted by Japanese Ministry of Environment is also very simple for participating amateur divers. However, on the items such as coverage, observers need much more experience for obtaining reliable values.



Source: JICA Expert Team

Figure 2.6.10 Relationship between Coverage of Coral and Transparency



Source: JICA Expert Team

Figure 2.6.11 Relationship between Coverage of Live Corals and Rank of Siltation

b. Analysis of long-term monitoring data obtained by Albion Fisheries Research Center

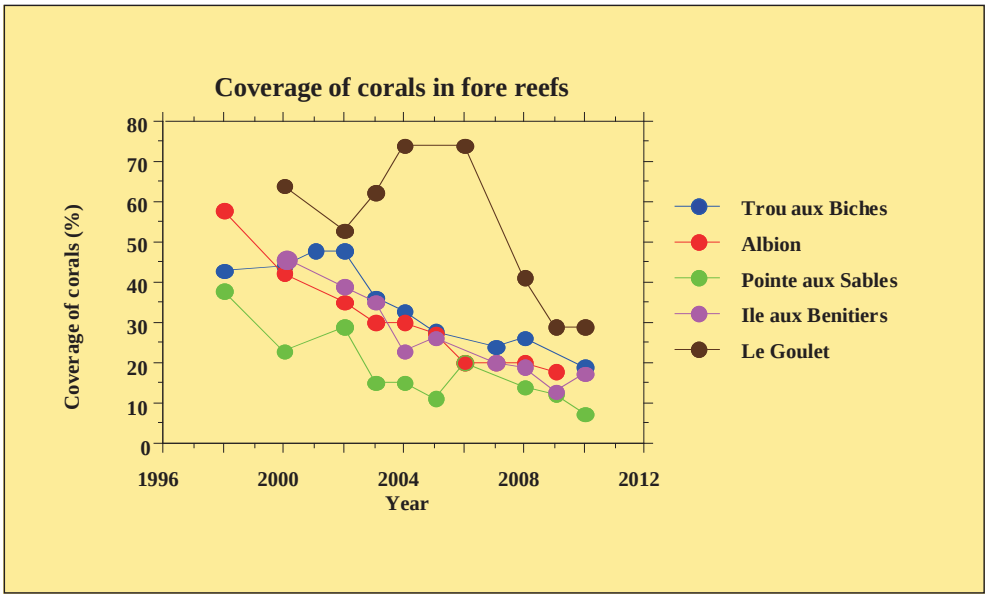
Albion Fisheries Research Center (AFRC) started the monitoring survey on live corals by the line transect method from 1998, and the survey is carried out once a year as a rule. In this item, annual change of live corals is analyzed based on the long-term monitoring data obtained by AFRC.

b.1 Method of the monitoring survey

Line intercept transects (LIT) method is applied for long-term coral reef monitoring in Mauritius by AFRC. It is used to assess the substrate cover at selected stations of the benthic community of coral reef ecosystem. 23 permanent monitoring stations have been established, of which, five are in the shore reef, five fore reefs and thirteen back reefs, representatives of the surrounding activities such as coastal development, agricultural, urbanisation and tourism activities. Each monitoring station has a GPS coordinates and three permanent transects of 20m have been set and demarcated by iron poles to which yellow fluorescent flagging tapes are tied. A 20m transect tape is laid on the substrate. Data on the substrate cover – categories (Acropora branching /ACB; coral foliose/CF; coral massive/CM; dead coral/DC; soft coral/SC; turf algae/TA ; Sand/SA, among others) are collected based on the categories as per the LIT method. The following results were obtained by the analysis of the monitoring data from 1998 to 2010. And, factors of coverage change at each site were obtained by interviews with the Scientific Officer, Mrs. Meera Koonjul.

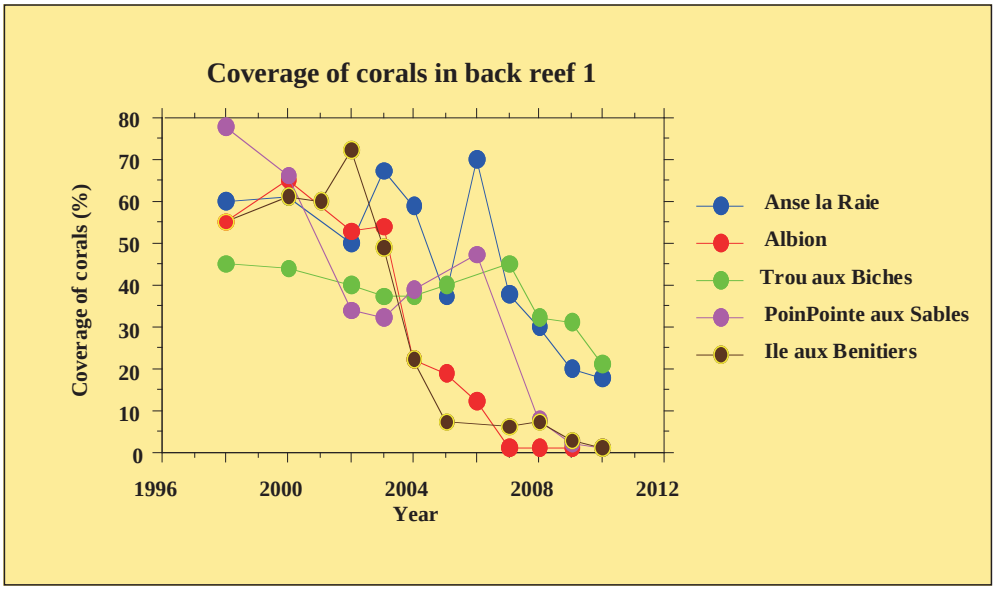
b.2 Results

Annual changes at five fore reef sites are shown in Figure 2.6.12. The five sites are Trou aux Biches, Albion, Pointe aux Sables, Ile aux Benitiers and le Goulet. Because fore reef (reef edge) is facing the open sea, environmental condition as habitat for live corals is better than other sites. However, as shown in Figure 2.6.12, coral coverage in the five sites are gradually decreasing and the coverage has halved since 2000. This fact shows that the mortality of corals is also high even if in the fore reef with better conditions for corals. Because of covering by the sediment from the land in Le Goulet, the monitoring site was changed in 2007.



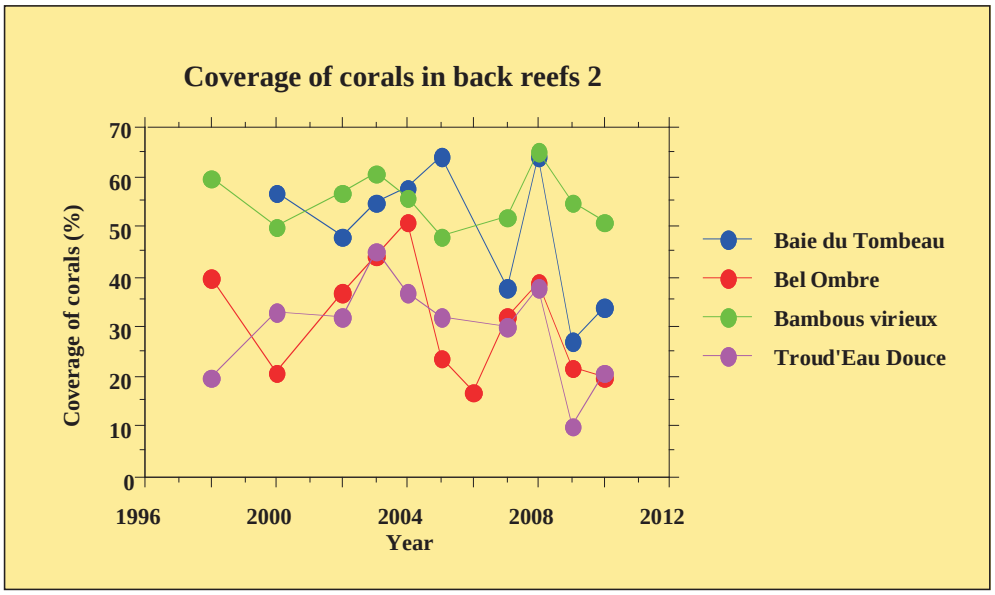
Source: AFRC

Figure 2.6.12 Annual Changes in the Coverage of Live corals at Fore Reef



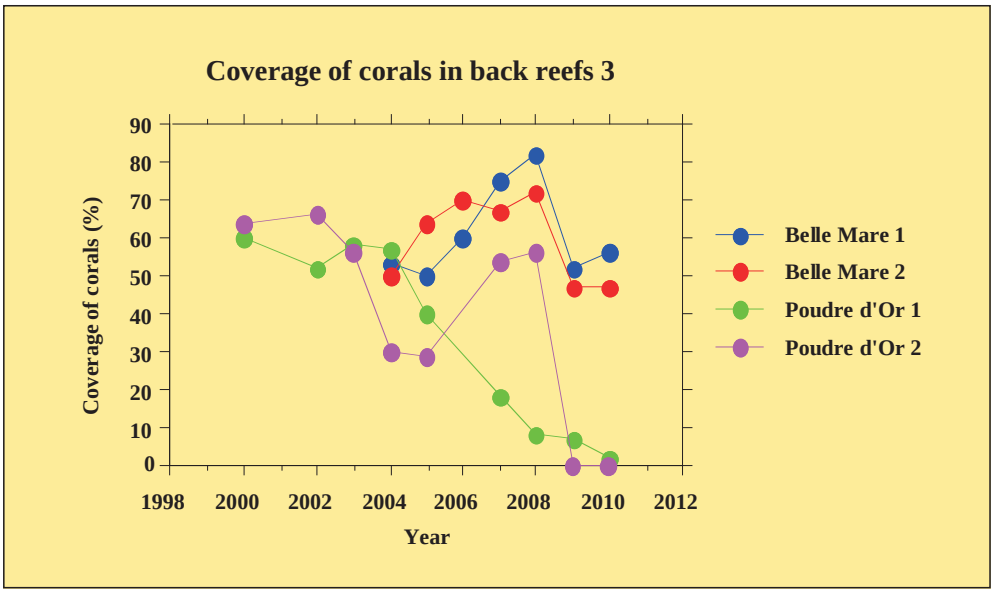
Source: AFRC

Figure 2.6.13 Annual Changes in the Coverage of Live corals at Back Reef (Part 1)



Source: AFRC

Figure 2.6.14 Annual Changes in the Coverage of Live corals at Back Reef (Part 2)



Source: AFRC

Figure 2.6.15 Annual Changes in the Coverage of Live corals at Back Reef (Part 3)

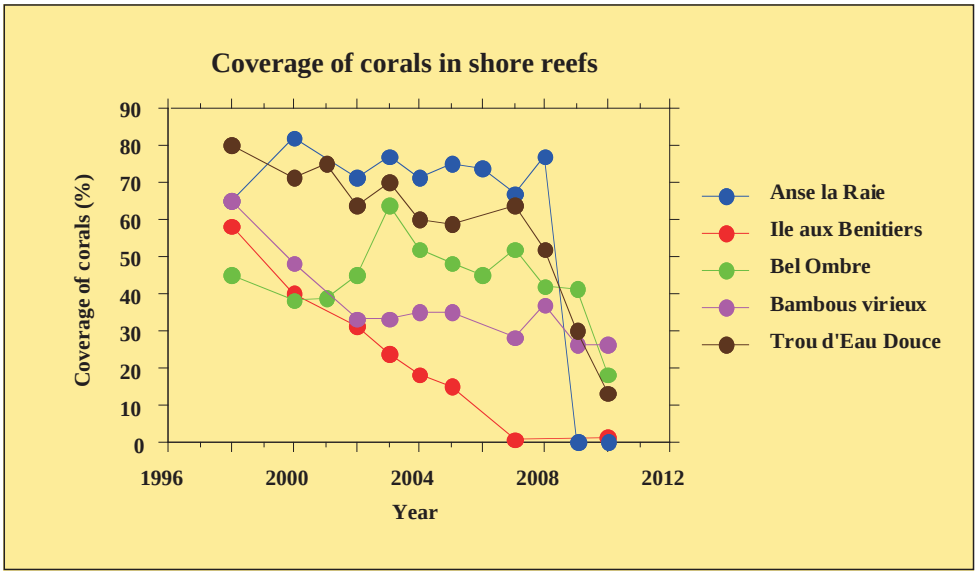
Annual changes in the sites of back reef are shown in Figure 2.6.13, Figure 2.6.14 and Figure 2.6.15. Figure 2.6.13 shows the results of five sites, i. e. Anse la Raie, Albion, Trau aux Biches, Pointe aux Sables and Ile aux Benitier. In the three sites of Albion, Pointe aux Sables and Ile aux Benitier, the coverage was higher than 50 % in 1998 but was nearly 0 % in 2010. In Albion and Pointe aux Sables, the mortality factor seems to be coral-bleaching events happened in 2003 and 2004 with siltation. When the monitoring survey was started in 1998, Ile aux Benitiers was selected as a control. The coral communities in this area showed high coral coverage at the time and were typical coral-reefs of Mauritius. However, coral-bleaching events were observed also in this area, and the coral coverage was nearly 0 % in 2010. The coverage in Anse la Raie decreased temporarily by the coral bleaching event in 2004, but recovered to 70 % in 2006 and decreased again in 2007. According to Mrs. Meera Koonjul, this seems to be a mistype. Algal bloom happened in this area in 2011 and all of the coral died by the cover of the micro algae during a short time in summer. So live corals are seen only in Trou aux Biches (21%) out of the five sites.

The results of Baie du Tombeau, Bel Ombre, Bambous virieux and Trou d'Eau Doucea are shown in Figure 2.6.14. The coverage in three sites, namely Baie du Tombeau, Bel Ombre, and Trou d'Eau Douce shows up and down at first, but now tend to decrease slightly. In Bambous virieus, the coverage was over 50 %, which is the same as 10 years ago, but siltation at back reef has become a problem recently.

Figure 2.6.15 shows the results at the two sites of Belle Mare and two sites of Poudre d'Or. The coverage at two sites of Poudre d'Or was very high, about 60% in 2000, but it became nearly 0 % in 2010. Main cause of this reduction at the first site in Poudre d'Or was the coral-bleaching event in 2004 and algal bloom of microalgae in 2009 at the second site of Poudre d'Or (Photo 2.6.1). At the two sites of Belle Mare, branching *Acropora* are abundant and the coverage maintains 50 % still now, but a part of branching *Acropora* is dead from the cover of green filamentous algae (Photo 2.6.2).

Photo 2.6.1 Algal Bloom (by AFRC)

Photo 2.6.2 Corals covered by Green Algae



Source: AFRC

Figure 2.6.16 Annual Changes in the Coverage of Live corals at Shore Reef

Shore reef is developing close to coastal line, so it is easily affected by the human activities. Figure 2.6.16 shows the survey results at the shore reefs of Anse la Raie, Ile aux Benitiers, Bel Ombre, Bambous virieux and Trou d'Eau Douce. The coverage of these five sites in 1998 was from 45 to 80 %, but it was nearly 0 % at two sites, Anse la Raie and Ile aux Benitiers, in 2010. Algal bloom (Photo 2.6.1) happened during the summer of 2009 was pointed out as a main cause and the main cause of the reduction in Ile aux Benitiers seems to be the coral bleaching event in 2003. At other three sites, the coverage tends to decrease slightly, but maintained 10 ～30%. It is said that the cause of decreasing is the coral bleaching events in Bel Ombre, and inflow of earth and sand from land in Bambous virieus. Coral bleaching events and siltation seem to be causes in Trou d'Eau Douce.

b.3 Present condition and issues of coral reefs in Mauritius

According to the monitoring by AFRC, the coverage of live corals was 51.4 % (average) in 2000, but it decreased to 19.2 % in 2010. As a result of present monitoring survey by the spot-check method, the coverage of live corals was 27.2 % on average. Taking account of these facts, coral reefs in Mauritius are not healthy and will gradually die off without mitigative

action. The situation is expected to be more serious by 2020 because the coverage of live corals is estimated to be only 7 %. Mrs. Meera Koonjul, scientific officer of AFRC, and Dr. Ruby M. Pillay made valuable comments on causes of this long-term degradation in coral reefs of Mauritius.

Problems emerged from the monitoring surveys and the interviews are as follows:

(1) Long-term decrease of live corals

(2) Decrease in recruitment of juvenile corals to coral reefs in the lagoons

(3) Rapid decline of tabular-type coral that was dominant in 2000

(4) Local extinction of some coral species

(5) Several coral-bleaching events in 2003, 2004 and 2009

(6) Eutrophication in lagoons

(7) Algal bloom in the summer of 2009 and 2011

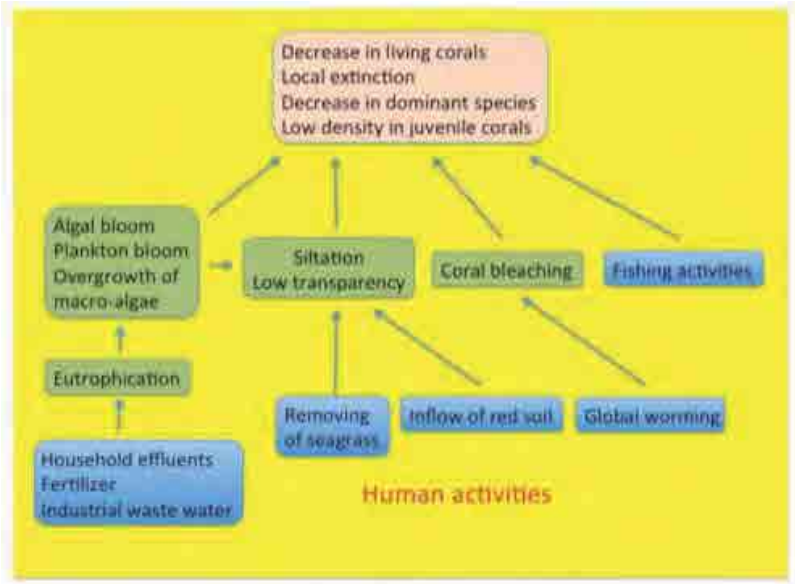
(8) Overgrowth of macro-algae as a competitor of corals

(9) Siltation in lagoons

(10) Decrease in transparency in lagoons

(11) Fishing activity by large nets in lagoons

(12) Pole and anchor damage by boating activities and coastal development and tourism related activities



Source: JICA Expert Team

Figure 2.6.17 Relationships among Problems

(1) Long-term decrease of live corals

As shown in the long-term monitoring by AFRC, the coverage of live corals on average decreased from 51.4 % (evaluated as good) in 2000 to 19.2 % (evaluated as bad) in 2010. Also, average coverage was 27.2 % by the present monitoring surveys. This value is also evaluated as

bad. In any way, coral reefs, as important tourist attraction, are facing a crisis in Mauritius that tourism is an important income.

(2) Decrease in the recruitment of juvenile corals to coral reef in the lagoon.

Density of juvenile *Acropora* (less than 5 cm in diameter) was very low at shore and back reefs of Mauritius in comparison with density at coral reefs of other countries. Juveniles appeared only at 9 sites out of 44 sites (except for 6 seagrass beds) and the density was only 0.1/m^2 in 4 sites out of 9 sites. The highest density (1.1/ m^2) was observed at the back reef in Pte. d'Esny, and then Porte Lafayette (0.8/ m^2) and Tamarin (0.7/ m^2) (Tables 2.3.20, 2.3.21 and 2.3.22). Empirically, if recruitment of 10/ m^2 continues for several years, the coverage of corals is over 50 % after 10 years. Taking this value into consideration, natural regeneration seems to be very hard in the coral reefs of Mauritius.

(3) Disappear of tabular-type coral dominated in 2000

In 2000, the tabular-type coral, *Acropora cythera*, was very abundant and sometimes the average size of colonies was over 6 m in diameter in the lagoon of Mauritius. The very large colony over 16 meters in diameter was observed inside the Blue Bay in 2002, but unfortunately the big colony died of the coral-bleaching event in 2009. Most of this dominant species are rapidly disappearing in the lagoon of Mauritius. During 15 minutes of the present monitoring survey in each site, sites observed over 5 colonies of *A. cytherea* are only 13 sites out of 44 sites. A large number of colonies were seen only in the site around Ile aux Aigrettes and Pte. d'Esny, located at south east coast of Mauritius. As mentioned above, the recruit of juvenile coral is very rare in the coral reefs, so the natural regeneration of *A. cythera* is also very difficult at present condition.

(4) Local extinction of some coral species

Pocillopora damicornis of Pocilloporidae were abundant in many sites during present survey. However, *Seriatopora hystrix* of the same family as Pocilloporidae was not observed in this survey. Both are common species in coral reefs with reproductive mode of larval release and are easily bleached, especially *S. hystrix* is the most weak species. According to Dr. Ruby M. Pillay of MOI (Mauritius Oceanology Institute), this species is one of the endangered species in the coral reef of Mauritius. There is a possibility of local extinction of this species. Some species such as other species of genus *Seriatopora* are also worried about local extinction. Early countermeasures to this problem are necessary.

(5) Several coral bleaching events in 2003, 2004 and 2009

When high seawater temperature (over 30°C) continues for a few weeks, the symbiotic zooxanthella in the coral body disappears or dies. Consequently, the white skeleton of the coral is seen through transparent body. If this condition continues for a few weeks, live coral starves to death. Generally, it takes 5 to 10 years for corals to become mature. If coral bleaching happens several times per 10 years, mature corals disappear. Ultraviolet ray is also known as the cause of coral bleaching. So, it is pointed out the tendency that coral bleaching is less in muddy water. Global warming is one cause of coral bleaching event, so international cooperation are necessary because it is difficult for one country to work out a solution to this international problem.

(6) Eutrophication in lagoon, (8) Overgrowth of macro-algae as a competitor of corals

Coral reefs normally develop in oligotrophic seas of tropical or subtropical area. So, plankton bloom and overgrowth of macro-algae are rare in coral reefs. However, overgrowth of macro-algae is common in the lagoons of Mauritius. For example, shore reef in Pointe des

Bambous was covered by macro-algae with the coverage of 70 % (Photo 2.6.3). The coverage of macro-algae was 50 % also in Poudre d'Or and Ile aux Benitiers, and was 20 % also in another seven sites.

Taking the chlorophyll a in the results of water quality (Figure 2.6.4) and coverage of macro-algae into consideration, eutrophication in the lagoons is apparent. Decomposition of macro-algae is a cause of nutrient loading in water bodies. Therefore, it is important to remove macro-algae from the lagoons in Mauritius for eutrophication control.

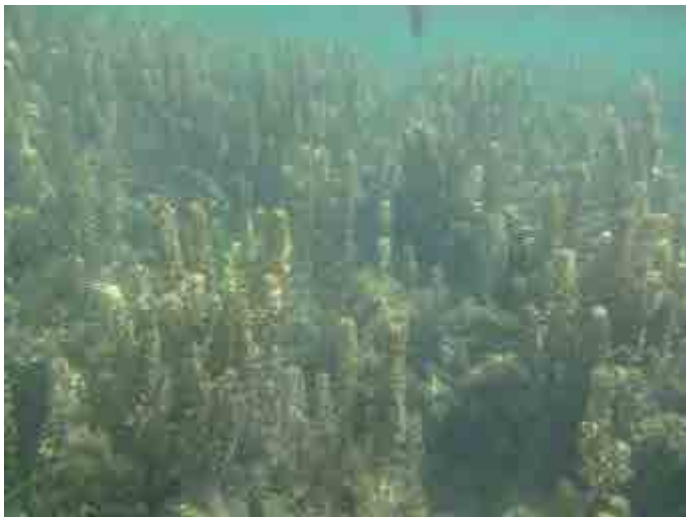


Photo 2.6.3 Macro-algae in the Shore Reef (Pointe des Bambous)

(7) Algal bloom in the summer of 2009 and 2011

In the summer of 2009, algal bloom happened and most of the corals died in Anse la Raie and Poudre d'Or. According to the scientific officer of AFRC (Mrs. Meera Koonjul), when it was very calm in summer at the both sites, brown micro-algae grew thick rapidly and covered the corals, consequently most of the coral died (Photo 2.6.1). Perhaps, one of the causes of this algal bloom is eutrophication in the lagoons.

(8) Siltation in lagoons

A cause of decline in coral reefs is a cover of fine sediment (silt) on the live corals. Accumulation of silt on the live corals consequently makes them die and ruins the health of the colonies. Siltation is also very serious for juvenile corals settled inside small holes. As shown in Table 2.6.8, Table 2.6.9 and Table 2.6.10, there are 12 sites (mostly north coast of Mauritius) with heavy or very heavy siltation, and these areas are not in a healthy condition for live corals. Especially, the sites in Le Goulet and Poudre d'Or are very bad condition for live corals. Siltation is also remarkable in the north of Mauritius where there are many tourists.

(9) Decrease in transparency in the lagoon

In Mauritius, transparency in lagoons was over 10 m at least until ten years ago. But, the average of transparency of 50 monitoring sites decreased to 7.4 m. And, the sites over 10 m were only 18 out of 50 sites and consisted of 36% of the total. The sites less than 5 m (including 5 m) were 30 and consisted of 60% of 50 sites (Table 2.6.8, Table 2.6.9 and Table 2.6.10). Except for the south coast of Mauritius, transparency was generally low, especially in the north coast (Figure 2.6.8).

As shown in Figure 2.6.10, transparency has a positive relationship with coverage of live corals. So, improvement of transparency is also very important for live corals. It is also pointed out by the interviews that activities of remove seagrass from lagoon shoals in front of hotels bring about reduction of transparency and re-deposition of silt.

(10) Fishing activity by large nets in lagoons

Another problem emerged from the interview. Fishermen often catch fish by large netting in many lagoons, so live corals are destroyed directly by nets and trampled by fishermen during the fishing activities. Measures to reduce such impacts including setting aside areas where fishing is prohibited and/or limiting the fishing season in the future are considered necessary.

To conclude, the main threats facing coral reefs in Mauritius are coral bleaching, eutrophication, siltation and large nets fishing. All were caused by the long-term human activities (Figure 2.6.17).

2.7 Public Awareness of Coastal Conservation

Public awareness and opinion of coastal conservation was investigated to utilize it for the coastal conservation plan and selection of the demonstration sites. The investigations were conducted as interview surveys at 10 sandy beaches with serious erosion problem in Mauritius. The following shows overview of the objectives and results of the investigation.

2.7.1 Overview of the questionnaire

- Objective
  - Collect the damage records / information at coastal area by cyclones
  - Confirm the residents' awareness / demand for coastal conservation
  - Improve the residents' awareness for future coastal disaster and understanding for countermeasures for the disasters.
  - Investigation about the WTP (Willingness to Pay) for coastal conservation

- Targets
  - From the objective to collect information about the past damage, residents at coastal areas were chosen for the target of questionnaires because they seemed to have some experiences of past disasters.
  - Locations shown in Figure 2.7.1 were selected as 10 sandy beaches with serious erosion problems in Mauritius.

- Number of samples: 300 (more than 30 at each location)

- Implementation period: About three weeks in February 2013

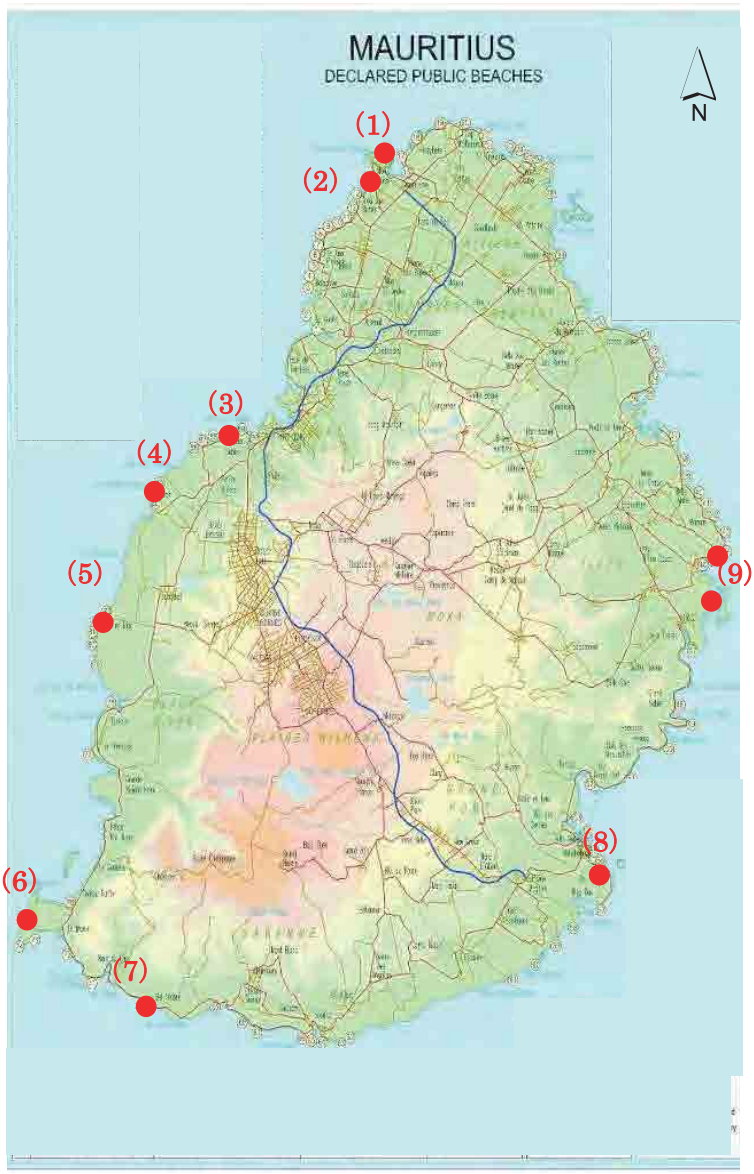
- Methodology
  - Face-to-face interviews were employed as the survey method to improve the residents' understanding of the contents of questionnaires.

- Main contents
  - According to the objectives, the main contents of questionnaire are as follows. Details are shown in Appendix 2.3.5 of ITR.

    1) Damages on the coastal area by a cyclone (one event of extreme weather conditions)
    2) Residents' awareness on erosion tendency over the long term

3) Residents' awareness on future coastal disasters caused by climate change
4) Desirable adaptation methods to the beach erosion and SLR (Sea Level Rise)
5) WTP for the desirable coastal conservation

Target Areas beaches, 9 districts)
(1)The Vale (Pte. aux Cannoniers)
(2) Mon Choisy
(3) Pte. aux Sables
(4) Albion
(5) Flic en Flac
(6) Le Morne
(7) Bel Ombre
(8) Pte. d' Esny
(9) Q. Cocos Vge, T. d'Eau Douce, Ile Cerfs



Source: This figure was processed by JICA Expert Team based on the map of MOESDDBM

Figure 2.7.1 Target Areas for Questionnaire

a. Overview of the Survey Results

Overview of the survey results are shown below and the details are shown in the Supporting Report (7. Survey Results of Public Awareness).

Table 2.7.1 shows the summary results in terms of ①Degree of residents' demands for the coastal conservation and ②Degree of residents' awareness for the coastal environment. The former relates to the possibility of the project implementation and the latter does to the participatory coastal management after the implementation.

Table 2.7.1 Evaluation used for the Selection of the Demonstration Sites

Selection Standard	Evaluation item	Overall Trend	Regional Characteristics
①Degree of residents' demands for the coastal conservation	1) Erosion amounts recognized by residents until present	Erosion amounts ranged from 1m to 5m accounts for highest percentage, which is not a large amount	At coastal areas shown below, amounts of beach erosion recognized by residents were larger than those of other areas and the project implementation was strongly requested. [Specific areas] Flic en Flac, Pte. aux Sables, Pte. aux Cannoniers, Mon Choisy, Pte. d'Esny
	2) WTP (Willingness to Pay) for coastal conservation	Respondents who showed WTP was not so high and it accounts for only about 25%.	At coastal areas shown below, number of respondents who showed WTP are greater than those of other areas, which shows their higher demands for the coastal conservation. [Specific areas] Flic en Flac、Albion、Pte. aux Cannoniers
② Degree of residents' awareness for the coastal environment	1) Aspects of most serious coastal disasters (protection, environment, utilization)	"Protection" and "Environment" account for about 20%, respectively. It is considered that residents take environmental aspects seriously as well as the protection.	At coastal areas shown below, "environmental impacts" caused by coastal disasters were considered more serious than other areas, therefore, residents' awareness about coastal environments is considered to be relatively higher at these areas. [Specific areas] Albion, Mon Choisy (about 40%)、Pte. d'Esny、Pte. aux Sables (about 40%)
	2)Desirable coastal conservation countermeasure	"Seawalls and revetments" accounts for highest percentage of about 50%, followed by "Beach nourishment", which accounts for about 30%.	At coastal areas shown below, beach nourishment (i.e. restoring natural sandy beach) was more desired than the other areas, therefore, residents' awareness about coastal environments is considered to be relatively higher at these areas. [Specific areas] Pte. aux Cannoniers、Mon Choisy
	3)Reasons for showing WTP	"Improvement of protection aspect" accounts for highest percentage of about 50%, followed by environmental and utilization aspects, which account for about 30%	At Flic en Flic, "improvement of coastal environment" accounts for higher percentage than other areas, therefore, residents' awareness about coastal environments is considered to be relatively higher at this area.

Source: JICA Expert Team

2.8 Coastal Environment Database

Organization and creation of database of both information and analysis result obtained through basic survey on situation of coastal erosion, ecological state of the coral, speculation of current damage and future risk, use of beach, coastal conservation facilities such as seawalls and jetties, asset and population, social conditions such as social capital improvement, and information about natural conditions such as hydrographic conditions, and landform shall be made. Creation of database of information shall be basically performed in GIS system and by using GIS function.

2.8.1 Existing Database

In Mauritius, geographic information database including coast has been created by many government agencies and has been used. Related organizations offered many of these data for this survey. All data obtained are showed in reference and primary data of them are as follows.

(1) Political Boundary Maps
Main Land, Province, Village Council Area (VCA)

(2) Infrastructure Map Data
Roads, Rivers, Ponds, Bridges etc.

(3) Thematic Maps
Geology Map, Soil Map, Land-use Map, Mangrove Distribution Map,
Contour Line Maps, Observation Location Map, etc.

(4) Other Maps
Nature Reserve Area Map, Coastal Park Area Map, Public Beach Location Map, etc.

Coordinate system of existing data was edited in the coordinate system of the WGS84, UTM coordinates, Zone 40South.

2.8.2 Making a database of data obtained from basic survey

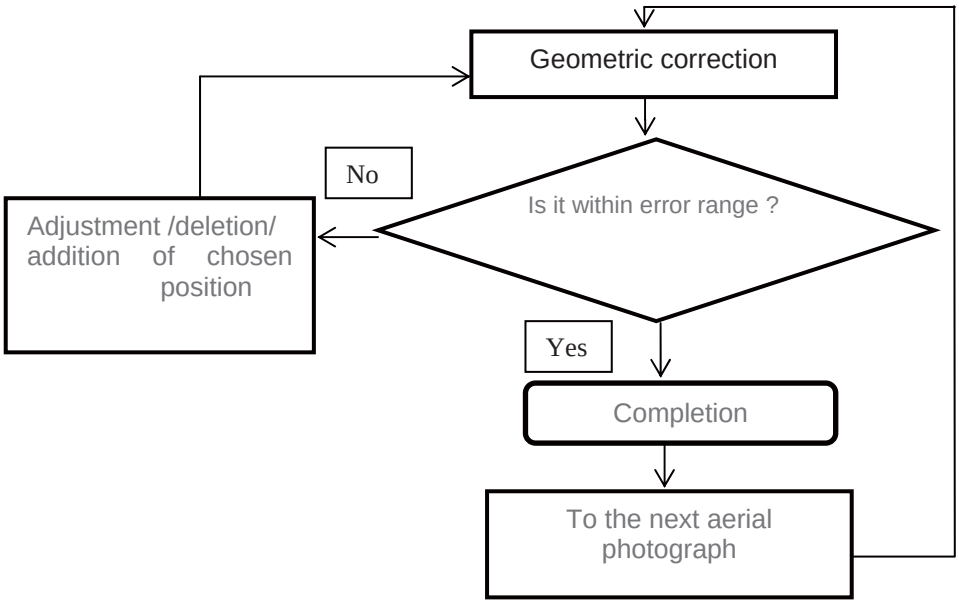
a. Shoreline Location Data

Shoreline location data of selected 13 coasts was created as a vector data using aerial photos taken in the past and satellite photos. Aerial photos taken in 1967, 1975, 1991 and 1997 - 1999 were used. Satellite photos obtained from Google taken in 2008 and 2011 – 2012 were used. Procedure of creating shoreline location data was as follows.

a.1 Geometric Correction

Coordinate setting was performed by geometric correction according to seashore, photography year and aerial photograph. In addition, WGS84 was used as coordinate form. As for satellite photos of 2008, coordinate setting had already been performed, and geometric correction was carried out by the following method: First, choose a point (seaside reef, street crossing, etc.) on both the satellite image (which has coordinates) and the aerial photograph (for which the coordinates are unknown). Second, coordinates can be set on the aerial photograph by plotting the point of each photograph. In addition, depending on the point, there is a possibility that error becomes large because of adopting the least-squares method. Therefore whether or not coordinate setting is right depends on the value of this error. If error is within tolerance level, coordinate setting ends. Tolerance level of this error is as follows.

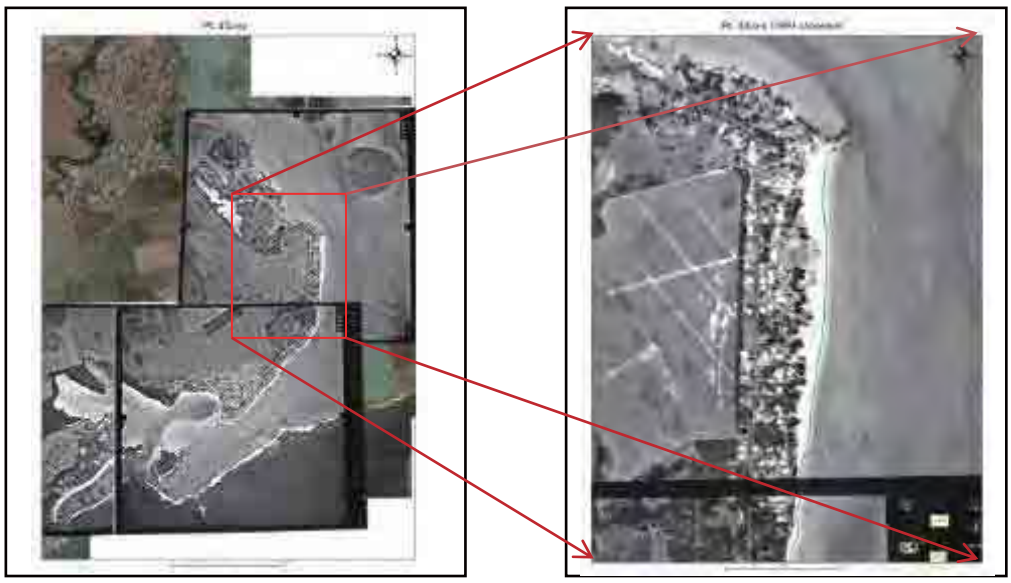
(1) Allowance limits of error less than 1.0m
(2) Average error less than 0.7m



Source: JICA Expert Team

Figure 2.8.1 Process of Geometric Correction

Because aerial photograph is a central projection, when geometric correction of aerial photographs is performed, error becomes larger with moving away from the center (because of single photograph). Therefore this time's geometric correction used a projection transformation method.



Source: JICA Expert Team

Figure 2.8.2 An Example after Geometric Correction

Figure 2.8.3 Shoreline Data after Geometric Correction

a.2 Making of Shoreline Data

After geometric correction of aerial photos and six photography periods of satellite photos (1967, 1975, 1991, 1997-1999, 2008, 2011-2012) ended, shoreline was input using a digital function of ArcGIS according to each year and shoreline database was created.

Source: JICA Expert Team

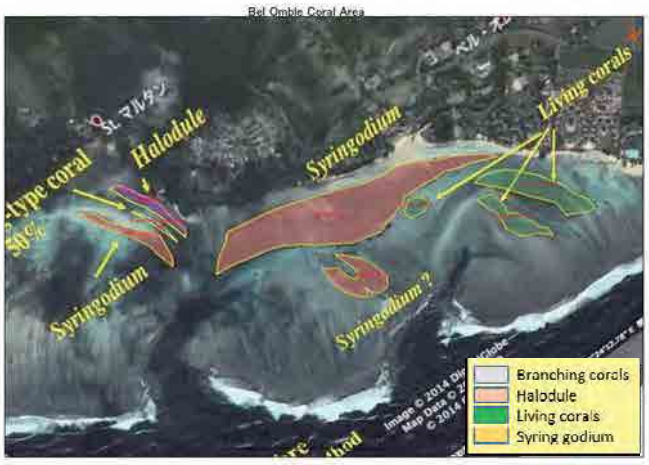
Figure 2.8.4 A Finished Product for the Shoreline Database

b. Distribution of Coral and Seagrass

The distribution of coral and seagrass were interpreted by the aerial photograph and spot-check (by snorkel) survey in the project as shown in Figure 2.8.5 and Figure 2.8.6. The database was made employing the same method of shoreline database by the digitization and geometric correction.

Source: JICA Expert Team

Figure 2.8.5 Interpretation of Coral and Seagrass

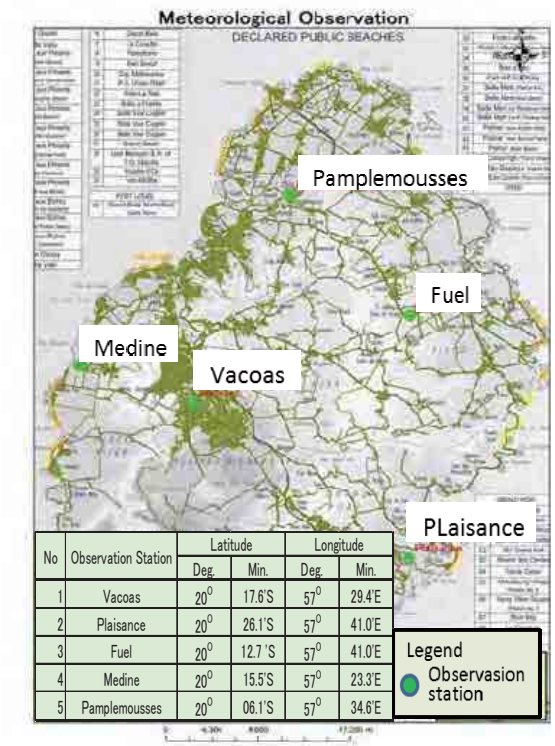


Source: JICA Expert Team

Figure 2.8.6 Interpretation Results of Coral and Seagrass

c. Air Temperature and Rain Data

Temperature data and precipitation data of five places were collected and they were displayed in ArcGIS. Work procedures were as follows: Position coordinates of five places (latitude and longitude) were converted into coordinate system WGS84 using coordinate conversion software and XY coordinates of UTM were created. Since south latitude becomes negative in this coordinate system, it was decided to convert into XY of UTM which Mauritius utilizes currently and use it. These XY data were read in ArcGIS and then weather observation location database was created. When observation location diagram is displayed and one point to search is hit by mouse, view of observation record is displayed.



No	Observation Station	Latitude		Longitude	
		Deg.	Min.	Deg.	Min.
1	Vacoas	20°	17.6'S	57°	29.4'E
2	Plaisance	20°	26.1'S	57°	41.0'E
3	Fuel	20°	12.7 'S	57°	41.0'E
4	Medine	20°	15.5'S	57°	23.3'E
5	Pamplemousses	20°	06.1'S	57°	34.6'E

Source: Data metro from AAP (African Adaptation Programme)

Figure 2.8.7 Observation Position Map

	Temperature				
	1	2	3	4	5
1996-01	30.3	31.0	31.5	32.0	29.5
1996-02	31.5	31.0	32.0	32.2	31.5
1996-03	32.5	30.0	30.0	31.3	31.5
1996-04	31.0	31.2	29.5	29.5	29.0
1996-05	27.2	27.5	28.0	27.0	26.5
1996-06	27.0	27.5	27.5	27.5	26.5
1996-07	25.9	24.6	24.9	25.5	25.5
1996-08	26.0	26.7	26.0	26.2	26.0
1996-09	26.1	27.0	26.7	27.0	27.2
1996-10	27.2	27.2	28.5	27.5	27.9
1996-11	28.5	29.0	29.5	31.4	31.5
1996-12	31.5	31.0	32.5	32.5	32.9
1997-01	32.4	32.0	31.5	31.9	31.5
1997-02	30.0	30.3	30.7	31.0	30.5
1997-03	30.5	31.5	31.0	32.2	29.0
1997-04	32.0	31.0	30.0	29.5	31.5
1997-05	28.5	30.0	29.2	32.5	29.5
1997-06	26.0	26.0	26.5	28.0	27.7
1997-07	25.5	26.0	25.0	25.0	26.0
1997-08	25.5	25.0	25.5	25.0	25.5
1997-09	25.5	24.0	25.5	25.0	25.5

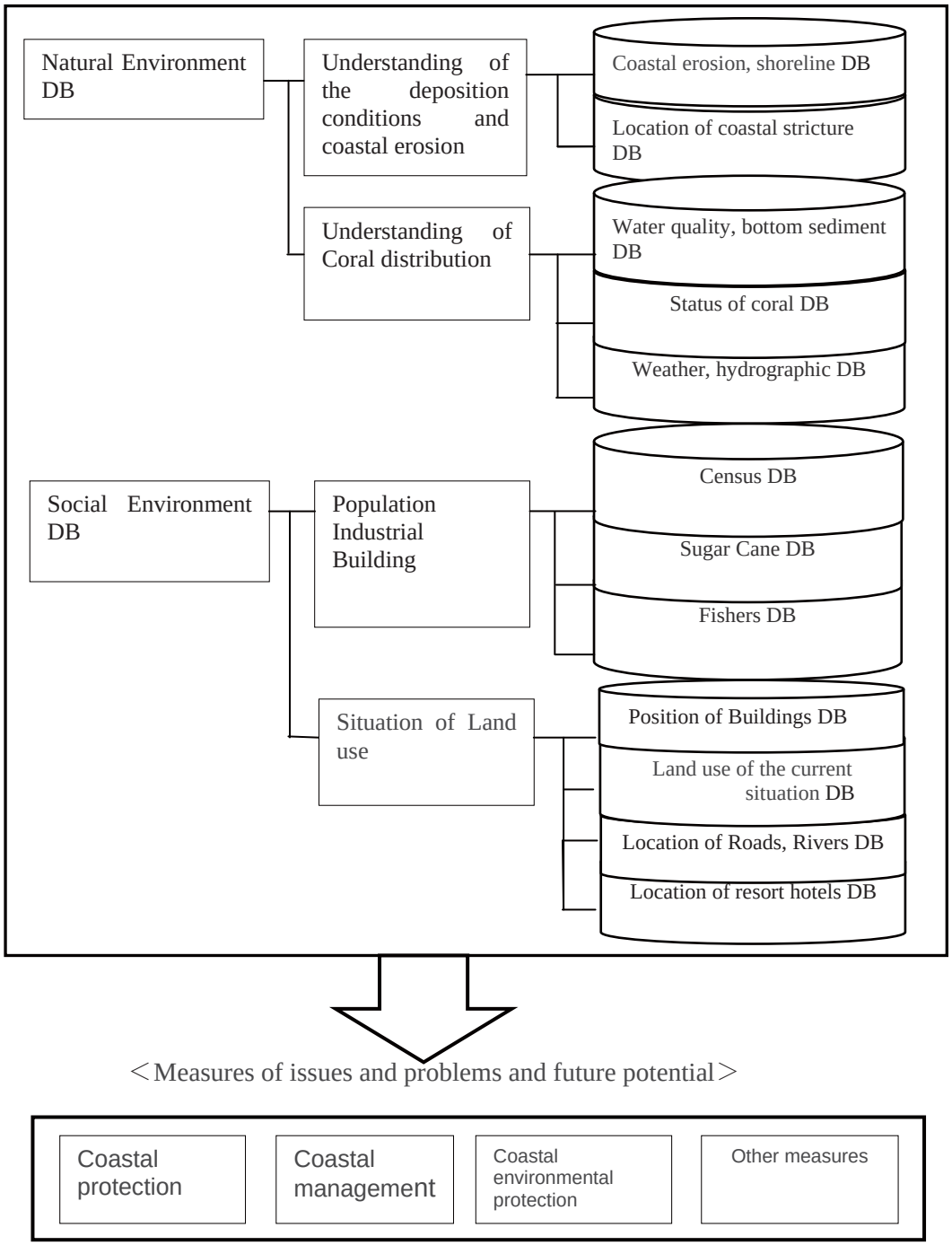
Figure 2.8.8 View of Observation Record

2.8.3 Utilization of Database

Some typical examples of utilization of coastal environmental database are cited as follows; quick response to disaster and coastal erosion, enabling rapid pinpointing of problems and challenges of various environments of coastal areas and undertaking of measures, and appropriate coastal management. In order to perform such comprehensive coastal management, it is very important to extract information quickly and consider from various perspectives based on weather (climatic) and sea condition databases (DB), shoreline and coastal structure DB of the past, coral situation DB, and bottom sediment survey DB. In addition to natural environment and long-term changes of coastal situation, it is also important to create a database of population and industry of coastal area, and of social environment such as land use, other conditions in order to establish a comprehensive coastal management plan. This case includes census information, land use DB, infrastructure status DB, distribution DB of buildings and the like.

In future, it will be increasingly important to make databases of results of continuous monitoring and to accumulate such information. As well as to analyze these data, and finally to utilize them in the development of short-term / medium-to long-term coastal protection plan. In this project, demonstration projects, monitoring of water quality and coral, and monitoring of various types of shoreline in monitoring coasts are carried out, but what matters is to accumulate these data and to create an environment that is easy to use these data. (See Figure 2.8.9)

＜Extraction of issues and problems of the coastal environment＞



Source: JICA Expert Team

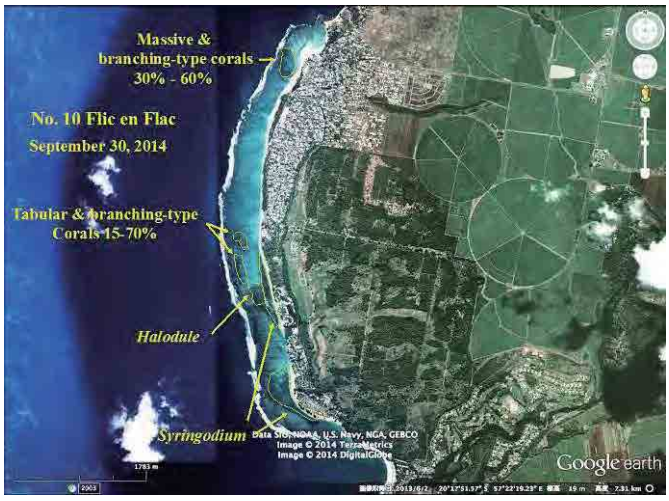
Figure 2.8.9 An Example of Use of Database

One of the examples is shown in the case that the coastal erosion and accretion is related deeply to the existence of coral communities and seagrass beds in the lagoon. Figure 2.8.10 shows the survey results by a glass boat to determine the actual situation of areas that showed up as shadow-like areas on the satellite image in the lagoon at Flic en Flac. A part is coral community and the other is the seagrass bed such as *Halodule* and *Syringodium*. Figure 2.8.11 shows the overlapped results on the satellite image by the Quantum GIS.

The distribution chart of corals and seagrasses in lagoons and the measurements of those

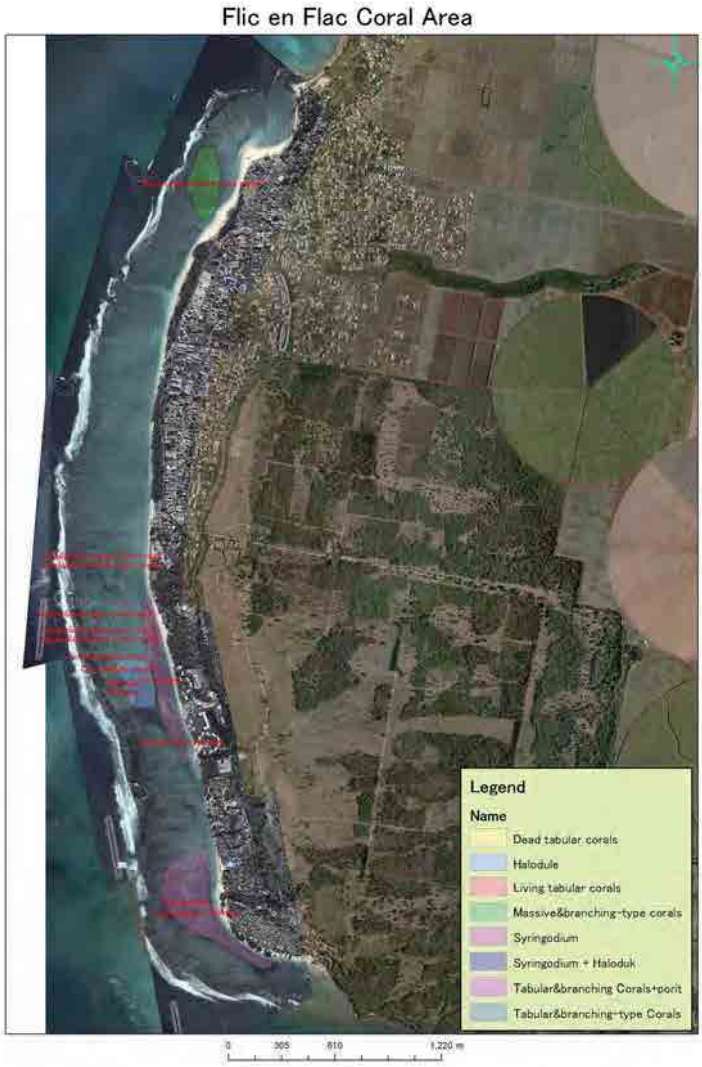
areas will be obtained from the database of satellite images and the monitoring results by helicopters and glass-bottom boats by Quantum GIS. The variation of coral and seagrass area can be analyzed based on the temporal data of the same lagoon.

For future utilization of the database considering intended use in Mauritius, the technology transfer, such as development of required database for coastal conservation in Mauritius, will be carried out with interactive discussion with the C/P in charge of database management to correspond with extension of future schemes, rather than simple unilateral approach of exercise.
Additionally, utilization of database is not only applied with ArcGIS mainly adopted for this technical transfer, but also Quantum GIS, open source software with versatility to ArcGIS, will be encouraged.



Source: JICA Expert Team

Figure 2.8.10 Results of Survey by Glass Boat in the Lagoon at Flic en Flac



Source: JICA Expert Team

Figure 2.8.11 Data Base of the Lagoon at Flic en Flac

Chapter 3

Policy of Coastal Conservation Plan

3 Policy of Coastal Conservation Plan

3.1 Problems of Coastal Conservation

Problems related to coastal conservation, rehabilitation and capacity building were investigated based on the basic study. These issues were classified into: (1) coastal management, which relates to all of the issues; (2) coastal conservation, which is the main topic of the project; (3) reef environment conservation; and (4) capacity development, as shown in Table 3.1.1.

Table 3.1.1 Problems for Coastal Conservation

Item	Problem
(1) Coastal Management	• Insufficient execution of coastal management and related planning • Partly ineffective management system • Measures for changes due to climate change and economic development in the future • Lack of monitoring • Lack of local involvement

(2) Coastal Conservation	• Harmony with protection, coast use and environment
	• Beach change caused by cyclones and setback
	• Coastal erosion and accretion
	  · Long term beach erosion
	  · Erosion and accretion caused by longshore drift
	  · Channel closure
	  · Sediment outflow from lagoons
	  · Cliff erosion
	• Wave overtopping and storm surge
	• Beach rehabilitation including removing of structures

(3) Reef Environment Conservation	• Degradation of coral • Eutrophication in lagoons • Competition between nature conservation, fishing and/or recreation
(4) Capacity Building	• Insufficient evaluation of EIA report • Lack of engineering ability

Source: JICA Expert Team

3.1.1 Coastal Management Issues

For coastal management in Mauritius, the national target and plan for the integrated coastal zone management was formulated. The MOESDDBM has implemented the ICZM plan through coordination with related organizations to provide coastal erosion mitigation measures. Along the coast, the land 81m from HWM is owned by the state as *Pas Géométriques* and there is a 30m setback. Construction is forbidden in this area. For other parts of the coast, the EIA system is in effect so any new development in the coastal zone must be reviewed and authorized first. In this sense, the management system and organization for the coast have been established. However, there are several challenges to the implementation as explained below.

Recommendations for the policy, regulation, organization and land use plan of six areas were proposed by Landell Mills (2010) and approved by the Government. It includes the coastal protection strategy, the protection and rehabilitation plan, the coastal special plan and the coastal management structural plan. The recommendation for ICZM is exhaustive and specific. The actual implementation has been delayed because of a shortage of human resources and financial support.

Although systems have been established, the results seem to be insufficient in some cases. For example the 30m setback could not be applied to the whole coast because most of it was already developed when the legislation was changed and there were already many hard structures present within the dynamic beach zone. New development in the coastal zone has also led to problems because of a lack of enforcement.

Climate change has caused sea level and sea surface temperatures to rise in recent years, which has led to coral bleaching. Moreover, this situation is expected to worsen in future. In general the coast has been eroded by the development of the coastal area. In the future, erosion issues will arise in Mauritius due to economic development plans. Though currently it has not been much of a problem, preparation is required for these future changes.

Coastal disasters and beach changes have been investigated in the basic study. It is very difficult to understand the actual conditions because of insufficient information which includes the topography and its change, waves as an external force, and damage conditions. The information of coral reef and seagrass in a lagoon is also limited though it is important for coastal conservation. The basic procedures of management are to seek an understanding of the current conditions by monitoring, estimating future conditions, analyzing problems, preparing and executing measures. The lack of monitoring makes it difficult to formulate plans and carry out management.

The challenges of integrated coastal zone management include solving the conflicts between different coastal uses and to keep the coast in good condition. In Mauritius, ICZM of MOESDDBM is responsible for the coastal management role, and has implemented coordination with relevant government agencies. However the exchange of information has been limited. Also the consensus with residents for removal of structures in the setback line is considered inadequate.

3.1.2 Coastal Protection Issues

As for coastal protection works, gabions have been installed in response to cyclone-induced erosion events and recently rock revetments have been constructed. Some of these structures were not considered to be effective for coastal use, environment or landscape of the beaches in question. Usually the measures are short term ones and a long term perspective is required.

One of the main problems for coastal conservation, which includes coastal erosion mitigation, is the response to the beach changes caused by cyclones and the disappearance of coral and seaweed. The basic principle is to keep the beach in a natural state and to rehabilitate it to its original condition. Setback and removing structures have been carried out as measures. It is necessary to consider the validity of the 30m setback and how to deal with buildings that have already been build when the set back was only 15 meters.

With respect to beach erosion and accretion, for some beaches where there is long-term erosion the erosion mechanisms and measures need to be investigated. Separate measures

will also need to be investigated for beaches being eroded by longshore sediment transport. Another issue needing grasping and dealing with sediment outflow from reefs. Erosion is also a problem on a 20km-long cliff coastline. Meanwhile on the accretion front, measures will need to be developed to prevent channels between islands from clogging with sand.

There are low lying coasts which are formed by small waves dissipated by the wide reef in front. The coast is easily affected by storm surge caused by high waves and will also be affected by future sea level rises. Although rock revetments have been constructed along the coast, there are problems with coastal use, ecological environment and the landscape.

Coastal structures have been removed to rehabilitate the beach to help it recover to its natural state. The effects and impacts have not been fully investigated, especially regarding cyclones. It will be possible to improve the beach not only by removing structures but by taking advantage of its natural features.

A risk map has been prepared for tsunami and flooding along the coast. However it is not reliable because the contours of the base map are at 10 m intervals and its accuracy is unreliable.

Measures proposed include sand nourishment for long term erosion and beach reprofiling for temporary changes due to cyclones. New sand sources are required because it is difficult to secure a supply of sand from land.

3.1.3 Coral Reef Conservation Issues

In coral reefs, coral is the source of beach sand and help to dissipate wave energy; as do seagrass and mangroves. Depending on whether any of these three are healthy (growing) or dying off will have a major impact on whether there is erosion or accretion of any particular beach. However the actual situation is not fully understood and the study of coastal conservation has become difficult.

Coral has important functions as the source of beach sand and the dissipation of incoming waves for coastal protection. The results of a long term monitoring survey show the coverage amount of coral in a lagoon decreased from 50 % in 2000 and to 20 % in 2010. Meanwhile, this Project found the coverage rate to be about 30 %. It is necessary to clearly understand the causes of the degradation and propose countermeasures.

There are several causes of the degradation such as an increase of sea surface temperatures, eutrophication, fresh water inflow, siltation, over growth of algae and recreational activities. It is difficult to find causes and countermeasures because the ecosystem of the coral is a complex system.

Eutrophication is pointed out as one the causes of coral degradation. Originally, coral exists in oligotrophic conditions and not in conditions where seaweed is growing by eutrophication. The water quality has been monitored in the lagoon. However, the analysis lacks accuracy and so it is difficult to investigate the measures.

Replanting coral is one of the promising measures for preparing suitable conditions for the habitat. Already the study of coral replanting has started. It can be implemented on a larger scale once its feasibility becomes clear.

Within a reef system there are various activities related to fisheries and tourism. Those activities contribute to beach erosion problems and the degradation of reef environments.

Regulation is necessary for conserving and appropriately using the reef ecosystem.

3.1.4 Capacity Building Issues

The Integrated Coastal Zone Management (ICZM) Division, the counterpart of this Project, is in charge of planning/designing coastal protection rehabilitation/improvement projects and the EIA Division is in charge of undertaking EIAs. However, it is deemed that the ICZM division is not always functioning effectively and therefore capacity building will be required.

Previous EIA reports on coastal protection projects were well prepared including the overall system of the project. Comprehension of the present conditions of the topography and natural environment, choice of items to be environmentally affected, and overall evaluation were well prepared. However, shoreline change analyses due to facilities construction and periodical monitoring have not been sufficiently conducted, requiring further improvement in the future. Also, the previous cases indicate that coastal erosion has been induced due to sediment transportation down drift as a result of facilities construction. Such cases should be improved and proper measures should be taken accordingly.

Previous design reports on the facilities construction prepared by the technical staff at MOESDDBM and consultants and their activities indicate that the technical capability on coastal phenomenon and the ability to consider measures against coastal problems, as well as the overall fundamental capability to examine independently have not been sufficient.

Through discussions with the counterparts about maintenance and management plans against scarps, a lack of engineering knowledge and technical capability has been detected. For example, a lack of knowledge on preliminary field surveys and determination of construction methods/plans has been identified.

Coastal conservation primarily aims at protective measures utilizing the natural characteristics as much as possible. Thus, it will not be necessary to prepare guidelines on facilities construction planning and designing. Instead, guidelines taking natural characteristics fully into account should be prepared. An important issue to be addressed for the guideline preparation is that there has been little research or experience about the coasts surrounded by reefs.

General technical guidelines have already been prepared in the USA, the UK and Japan. An important issue is how to adopt the guidelines to Mauritius. Especially, functional design to suit the usage and environment needs to be emphasised more, as the main focus of these guidelines is on protecting the coastline and countermeasure design aiming for beach stability. From this perspective, more focus should be placed on dissipating wave height and energy using coral reefs. Also, as a result of a lack of previous observation data, data on waves and some coefficients in facilities design are rather important to suit the conditions in Mauritius.

3.2 Risk in Coastal Zone

The risk of coastal disasters caused by coastal erosion and wave overtopping were assessed for the present and the future. The results show risks of coastal erosion at present and in the future risks of inundation by storm surges and waves, future sea level rise, the degradation of the coral reef system and future economic development. Because the analysis was based on current data, it is necessary to revise the results after a detailed study in the priority coast.

3.2.1 Risk by Coastal Erosion

As for the risk of coastal erosion, the risk of long term erosion and the risk of temporary erosion, according to approaching cyclones, are assumed. The beaches with long term erosion were identified. Regarding these beaches, the erosion amount can be estimated from the erosion rate and the risk can be investigated.

The erosion rate is divided into two classes: One class is set as 0.2 m/year. This rate can be clearly identified as erosion. Another class is set as 0.4m/year. This rate is assumed to be nearly the maximum erosion rate. The period is divided into three classes; 30 years, 50 years and 100 years respectively. 30 years is the period for the durable year of normal structures. The coastal erosion amounts for 30 years, 50years and 100 years are as follows:

Table 3.2.1 Relation with Erosion Rate, Periods and Erosion Amount

Erosion Rate/ Period	30 years	50 years	100 years
0.2m/year	6m	10m	20m
0.4m/year	12m	20m	40m

Source: JICA Expert Team

For the temporary erosion amount, according to approaching cyclones, the only quantitative data is the existing material on Cyclone Carol in 1960. The data shows the maximum erosion amount by Carol was about 13m. Although the stochastic cyclone scale related to Carol is unclear, the stochastic scale is assumed to be more than 50 years because no cyclone on the same scale as Carol has been reported previously. So, the risk by erosion is in range of this regulation.

In Mauritius, the beach is mostly state land. The houses and hotels are constructed on leased land. The buildings are under a setback regulation of at least 30m from the HWM. For the beaches affected by erosion, the erosion amount is 30m for the 50 year period, factoring in both the long term erosion amount and the temporary erosion amount. For the severely eroded, the erosion amount is 30m for the 30 year period and is equal to the setback amount. If the period is longer than these periods, the risk of erosion occurs.

For the cliff coast, the rock is basalt and hard enough to resist erosion. Accordingly, the risks are small compared to those of sandy beaches. However, there were examples which showed cliffs collapsing due to the impact of cyclone waves. The risks of cliffs have to be investigated at each coast.

3.2.2 Risk by Wave Overtopping and Storm Surge

Wave overtopping, inundation by high waves and storm surges occur. However the existing data to estimate the influence is limited and a clear outcome cannot obtained. The only existing data to estimate the damage by this disaster are the study results on Carol. According to the study, the maximum wave run-up height was 12 ft (4 m) on the cliff coast and is 9 ft (3 m) on the sand beach. The berm height of the beach is the same as the run-up height but the degree of risk is unclear.

There are coasts in Mauritius with wide reefs where ground level is around 2m or less that are also affected by wave overtopping even though the waves dissipate. At present, the beach profile has been formulated by the action of corresponding waves and tides. It is difficult to say that the risk of the beach is high compared to the other beaches even if the ground level is low.

However, the impact of sea level rise will become significant.

a. Effects by the Sea Level Rise

With regard to the sea level rise rate, the present average sea level rise rate of 3.9 mm/year is applied. The future risk by coastal erosion after the next 30 years, 50 years and 100 years are evaluated roughly as follows:

Table 3.2.2 Future Erosion Amount by the Sea Level Rise

Items/ Period	30 years	50 years	100 years
Sea Level Rise	0.12 m	0.20 m	0.39 m
Coastal Erosion	1.2 m	2 m	4 m

Source: JICA Expert Team

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

$E=C\times S$,

Where, E: Erosion amount due to SLR, C: coefficient of beach characteristic and S: amount of SLR. Although the coefficient C is reported to be from 50 to 100, the sediment transport is restricted by the coral reef in Mauritius. So, C is 25 by using 2.5 m for the height of sediment movement and 1/10 for the beach decline. The erosion amount is calculated by using this C. These results will be subject to change depending on future studies.

For the stable and accreted beaches at present, the risk is assumed to be small because the erosion amount, even when adding the change from cyclones and the erosion amount from the sea level rise, does not exceed the 30 m setback. As for the long term erosion on beaches, risks occur when factoring in the recent rise in sea levels and the effects after the next 100 years because the risks exceed the setback.

The sea level rise brings wave overtopping and increases the risk of run-up. The lowland, where at present the incident waves are small, will be affected relatively more than the high area. The lowland coast has to be analysed in detail.

b. Deterioration of Coral Reefs

Coral reefs are a source of sand on the beach and play a key role in coastal protection due to the attenuation capacity of waves. According to the results of long-term coral reef monitoring, the living conditions of coral are rapidly deteriorating and the coverage of coral decreased from 50% in 2000 to 20% in 2010. Although the deterioration of coral is not likely directly linked to coastal erosion, this leads to a variety of problems in the long term. But there is lack of data to estimate the effects quantitatively and the risk evaluation is very difficult.

3.2.3 Identification of Risk Area

The risks caused by coastal erosion and wave overtopping have been evaluated and the risk of an eroded coast was estimated and the setback was estimated against it. The risk of sea level rise was also estimated.

The long term risks of an eroded coast were identified by the erosion speed. Coastal areas with

speeds over 0.2 m/year and with 50 years exceed the present setback value of 30 m and are estimated as high risk. The following 12 coasts are high risk coasts: (1) Ponte aux Piments, (2) Mon Choisy, (3) Pte. aux Cannoniers, (4) Part of P.G. Choisy, (5) Q. Cocos Vge & T. d'Eau Douce, (6) Ile aux Cerfs, (7) Pte. d'Esny, (8) Saint Felix, (9) Le Morne, (10) Wolmar & Flic en Flac, (11) Albion, and (12) Pte. aux Sables from Table 2.2.8. Coasts with erosion speeds under 0.2 m/year are within the setback limit. In some coastal roads, the 30 m setback is not incorporated. The risk of these areas was not identified due to a lack of information.

Coastal roads situated on low-lying land which may have a risk of wave overtopping could not be identified because of a lack of topographical data. In the detailed study, Grand Sable is selected as an example of those coasts and is investigated in more detail.

3.3 Coastal Conservation Strategy

The present strategy of coastal conservation is proposed based on the following basic study results and the related issues for three objectives; coastal protection, coastal development and environmental conservation.

a. To maintain and make use of natural characteristics of the coast

Because erosion along the sandy beach in Mauritius is a natural and reversible process and coastal structures are not necessary, it is important to keep the coast in a natural state. Natural sandy beaches have to be maintained as a resource of tourism, which is one of the main industries in Mauritius. Coral reefs, which have important functions including supplying sand and wave dissipation together with the conservation of the ecosystem and fisheries, should be conserved and rehabilitated in a proper way.

b. To strengthen the coast's capacity to adapt to natural and socio-economic changes in future

It is necessary to strengthen the adaptive ability for the future sea level rise caused by climate change and economic development. Adaptive coastal management is going to be conducted by the following procedures: setting precise goals, implementing the plans, monitoring the conditions, and evaluating the results. It has to be done to accumulate and apply the information and past experience, and to develop measures and structures based on natural characteristics.

c. To integrate coastal management with the collaboration of stakeholders

The coastal zone has to be managed in an integrated way for coastal protection, nature conservation and coastal use. MOESDDBM will manage the coastal zone by making decisions and with the cooperation of related organizations. Each governmental organization plays their role for management with the participation of the local people.

The problems derived from the basic study are summarized as follows:

(1) Measures against beach changes caused by cyclones

(2) Conservation of deteriorating coral reefs

(3) Adaptation to future climate change and economic development

In the past, coastal erosion was caused by cyclones such as Cyclone Carol in 1960 and Cyclone

Hollanda in 1994 which led to the construction of gabions. The aerial photos show that the short term coastline changes are bigger than the long term changes. The variation in short term is ten times that of the long term changes. As a whole, the coastline is accreting and the eroded areas are limited.

The coral reef offshore of the beach becomes a sand resource and dissipates incoming waves. The coverage of living coral shows a change from 50% in 2000 to 20% in 2010 and shows 27% from the basic study in 2012. The deterioration of coral will possibly make an impact on the beach maintenance by decreasing the sand supply and increasing the number of incoming waves.

The issues for coastal erosion are measures against beach changes and the conservation of coral reef systems. Accordingly, preserving natural conditions of the beach and reef and rehabilitating if necessary, become a strategic plan. Because the natural environment is a resource for the vital industries of tourism and fisheries in Mauritius, the first strategic priority is preserving the natural state of the beach and to use its characteristics.

The second strategic priority is to respond to the future change of environmental conditions. At present, coastal disasters are not so severe. However, adaptation measures in the future are necessary for disasters caused by sea level rise or intensified cyclones, and the deterioration of coral due to the increase of sea temperatures. Coastal erosion will occur if the coastal area has been developed. In Mauritius, there is a possibility of this kind of situation arising.

In the past, countermeasures caused other erosion problems if they intended to serve only one purpose. In this sense, the importance of the integrated coastal zone management is emphasized. In the Project, the main concern is the mitigation of coastal disasters such as coastal erosion. It is necessary to harmonize the mitigation with nature conservation and coastal use. The third strategic priority then becomes to solve the conflicts among stakeholders and to integrate management.

3.4 Basic Policy for Coastal Protection Measures

Based on the strategy as stated above, the basic policy for the coastal protection measures are summarized as the following:

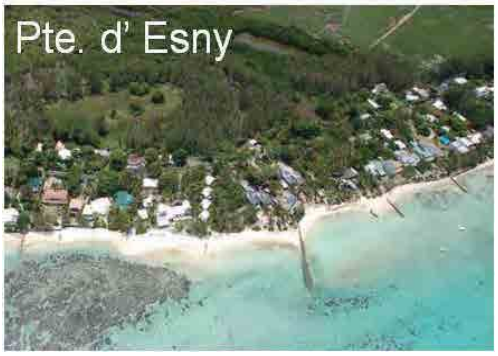
1. Natural beach without structures (Category A as shown in Figure 3.4.1) should be preserved with its present conditions because of the superiority of the natural environment and landscape. The only measures are nourishment and reprofiling with no structures.

2. For the coast with structures (Category B as shown in Figure 3.4.1), the measures are also basically nourishment and reprofiling. If tremendous maintenance is required for beach stability against longshore sediment transport, existing structures can be improved by adding new ones if necessary. The existing structures should be re-evaluated and reduced as much as possible. Reducing existing and new structures can promote the maintenance of the landscape and natural environment. The existing revetments should be setback or improved from vertical to gently sloping and permeable ones.

3. The sand or gravel for nourishment has to be the same particle distribution and color of the existing beach material. The black sand from the volcanic origin is not used for white coral beaches. The diameter of the nourished sand should be larger than the existing one.

4. Structural measures without nourishment do not increase the sediment volume and increases negative effects, which are larger than the positive ones from past experiences. They are not suitable for tourist beaches which have various coastal uses and need a good environment. So structural measures are not applied for tourist beaches. They can be used only for the protection of residences or important public facilities.

Example of Category A (Maintained Natural Beach)



Example of Category B (Beach without Sand or with Coastal Structures)

Source: JICA Expert Team

Figure 3.4.1 Natural Beach (Category A) and Beach with Structures (Category B)

5. Sand recycling is recommended only for partly eroded beaches but not in general (Category I and II as shown in Figure 3.4.2). So transporting sand from accreted to eroded areas as the solution in a sediment cell is recommended. In this case the beach should be wide enough for the 30 m setback and for accreting without erosion problems by recycling through sand mining.

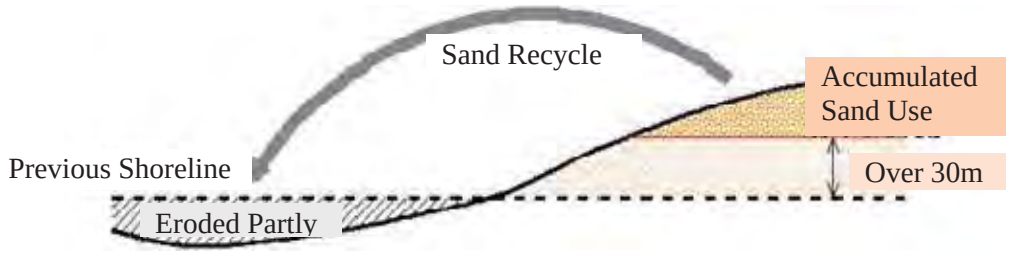
6. The eroded beach in total (Category III as shown in Figure 3.4.2) is nourished and maintained by the sand taken from the outside of the beach.

7. For long term maintenance of the beach, the reef environment will be conserved and improved as a policy to keep a continuous sediment supply. Together with sand nourishment, reef conservation is a priority for beaches where erosion was caused by the deterioration of coral reef.

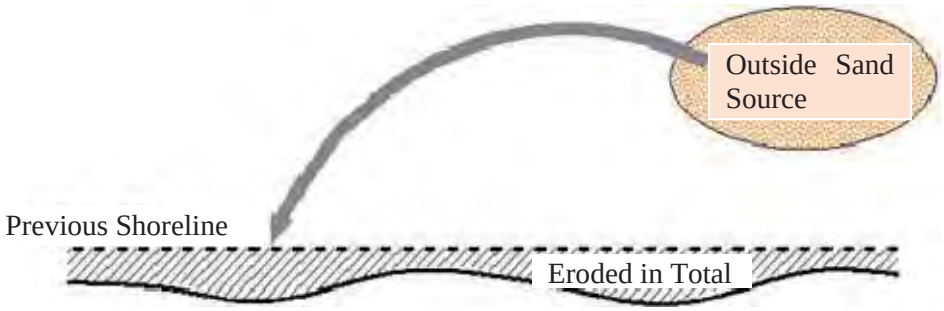
8. Maintenance of the setback line and review of the land use plan is one of the measures for future long-term climate change risks.

9. The sand for nourishment is procured in the most economical way considering the sediment budget in Mauritius and the mechanism of sediment transport at each coast. At present, the sand has been procured from only two sites of land. On the other hand, the

beach sand has increased in total though some beaches have been eroded. It is necessary to urgently review procurement methods which are sustainable and economical and factor in the possibility of sand transfer and the development of a new site.



Accreted Beach in Total (Category I) and Balanced Beach (Category II)



Eroded Beach in Total (Category III)

Source: JICA Expert Team

Figure 3.4.2 Classification of Coastal Erosion and its Measures

10. The coastal conservation activities should basically be implemented by following organizations.

Table 3.4.1 Procedure of Coastal Conservation and Corresponding Roles and Organization

Procedure	Details	Roles of the Government	Main organizations									
			MOESDDBM	MOESDDBM (BA)	MoHL	MoF(AFRC)	MoLG(DC)	MoTL	MMS	MOI	WMA	CWA
Basic study	Beach profile and bathymetric survey	Implementation	✓	✓								
	Coral reef and water quality survey	"				✓						
	Wave and current measurement	"	✓			✓			✓			
Coastal conservation plan	Coastal protection plan	Preparation/ Evaluation	✓									
	Breach use plan	"	✓	✓				✓				
	Land use plan	"	✓		✓							
	Environment	"	✓			✓						

	conservation plan										
	Consensus building	Implementation	✓								
Design and construction	Basic design	Evaluation	✓								
	Detail design	"	✓								
	Implantation plan	"	✓								
	EIA	Approval and license	✓								
	Consensus building	Implementation	✓				✓				
	Tender and contract	Preparation of related documents	✓								
	Construction	Management during construction	✓								
Management and maintenance	Maintenance of existing coastal structures	Implementation	✓	✓			✓				
	Maintenance of public facilities(e.g. parking, toilet)	"	✓	✓			✓				
	Monitoring of beach profile and bathymetry*1	Implementation, evaluation and feedback to the plan	✓	✓	✓				✓		
	Maintenance and monitoring of coral reef	"	✓			✓					
	Monitoring of water quality	"	✓			✓				✓	✓
	Management of land use	Management of set-back			✓						
		Review and permission for construction					✓				
		Management after construction	✓								
	Management of beach use	Management of illegal activities	✓	✓							

*1 Lessee is responsible for leased area, *"MOESDDBM" without special note generally means ICZM Div. *": same as above", *DC: District Council, *BA: Beach Authority

Source: JICA Expert Team

Chapter 4

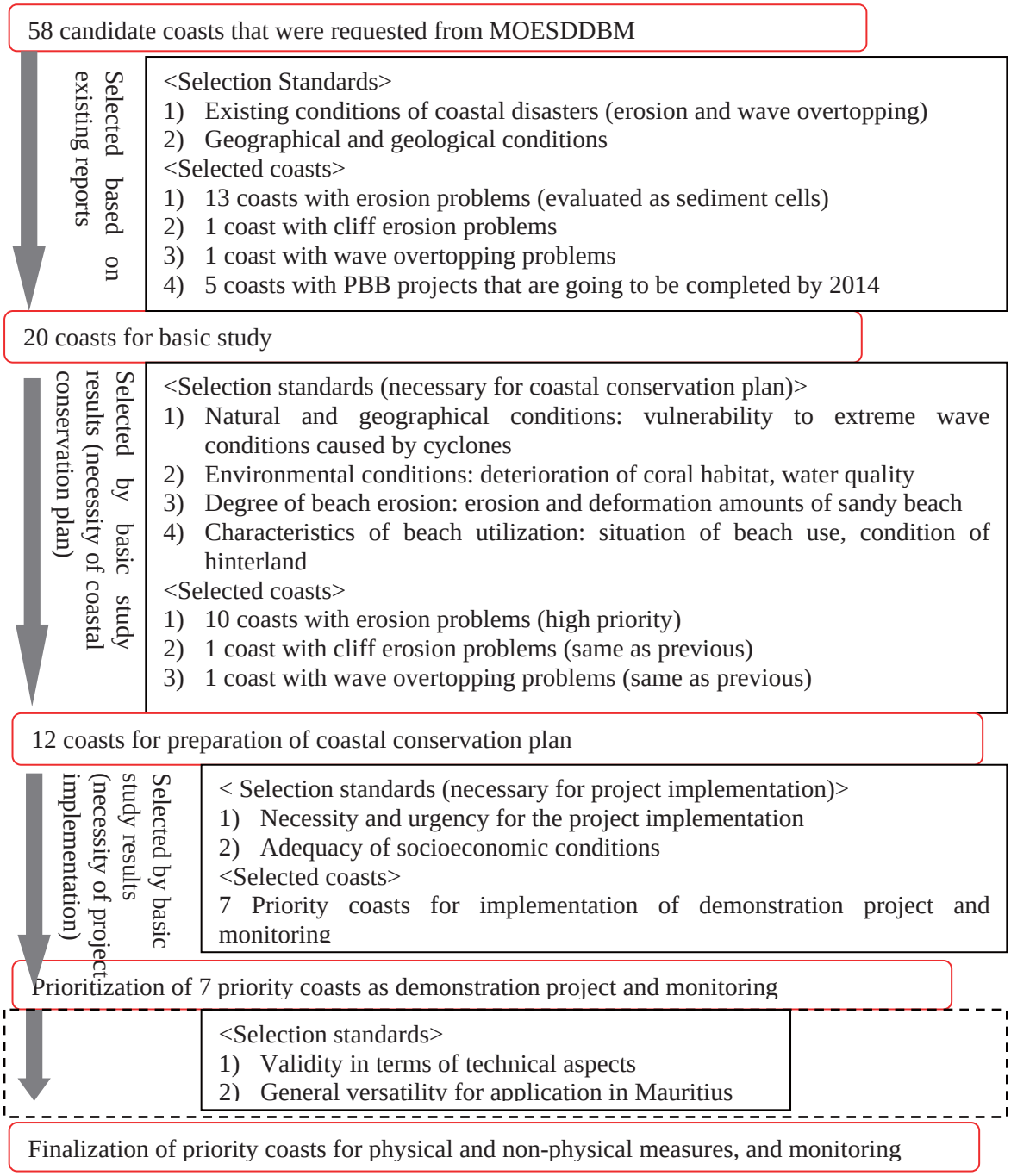
Coastal Conservation Plan for Priority Coast

4 Coastal Conservation Plan for Priority Coast

4.1 Selection of Priority Coast

4.1.1 General

For the formulation of the specific coastal conservation plan, 20 coasts were selected for basic study among 58 coasts which were requested from MOESDDBM. Based on the results, 14 coasts were selected as priority coasts for the coastal conservation plan. The flow of selection is shown in Figure 4.1.1.



Source: JICA Expert Team

Figure 4.1.1 Selection Flow of Priority Coasts

4.1.2 Selection of Basic Study Coast

Twenty coasts were selected to conduct the basic study including field survey and data analysis. Based on the existing reports about coastal conditions in Mauritius, the selection was conducted using two criteria; 1) existing conditions of coastal disasters such as erosion and wave overtopping, 2) geographical and geological conditions. Selected coasts include: 1) 13 coasts with erosion problems evaluated as sediment cells, 2) one coast with cliff erosion problems, 3) one coast with wave overtopping problems, 4) Five coasts with PBB projects. Selected coasts are shown in Figure 4.1.2.

Source: Processed by JICA Expert Team based on the map of MOESDDBM

Figure 4.1.2 Selected 20 Basic Study Coasts

Among the 20 coasts for the basic study, coasts with erosion and other coasts are shown in and Table 4.1.1and Table 4.1.2 respectively.

Table 4.1.1 Coasts with Erosion

No.	Name of Coast	Start Point	End Point
B1	Baie du Tombeau	Le Cocoterie	
B2	Pte. aux Piments / Trou aux Biches / Mon Choisy	Pte. aux Piments	Pte. aux Cannoniers
B3	Roches Noires	Bra de Mer des Fregates	Pte. de Roche Noire
B4	Bras d'Eau	Pointe	Bras d'Eau
B5	Belle Mare / Palmar	Mare	T, d'Eau Douce
B6	Ile aux Cerfs	Ile de L'est	Ile aux Lubines
B7	Pte. d'Esny	Pte. d'Esny	Blue Bay
B8	Riamble / Saint Felix / Riviere des Galets	Trou d'Esny	Riviere des Galets
B9	Bel Ombre	Beau Champ	Bel Ombre
B10	La Morne	Trou Chenilles	Pte. Pecheus
B11	La Preneuse / Tamarin / Flic en Flac	Grande Riviere Noire	Flic en Flac
B12	Albion (beach)	Albion	Pte. Petite Riviere
B13	Pte. aux Sables	Pte. aux Sables	

Source: JICA Expert Team

Table 4.1.2 Other Coasts

No.	Name of Coast	Remarks
B14	Bain Boeuf	PBB Project Coast
B15	Cap Malheureux	PBB Project Coast
B16	Poudre d'Or	PBB Project Coast
B17	Grand River South East	PBB Project Coast
B18	Baie du Cap Public Beach	PBB Project Coast
B19	Grand Sable	Coast with wave overtopping problem
B20	Albion (Cliff)	Cliff coast

Source: JICA Expert Team

4.1.3 Selection of Priority Coasts

Among the 20 coasts for the basic study, 14 coasts were selected for the formulation of the coastal conservation plan as priority coasts under the four criteria explained as follows:

a. Natural and Geographic Conditions

Each item was evaluated on a scale of one to three, with one being the lowest and three being the highest priority for selection for conservation planning. For example, in the first criterion, if the coast is located on north side of Mauritius where strong waves strike due to cyclones, the coast is high priority evaluated as "3". Also, the coasts with a convex shape or located at the ends of embayment where it is subject to stronger sediment transport, are evaluated as "3". Meanwhile, the coasts that have a low possibility of strong wave strikes or where less sediment transport is estimated are lowly evaluated as "1". Even if the coast is located at an area where strong waves strike, it is evaluated as intermediate,"2" if it has a wide coral reef to reduce wave energy. The evaluation criteria area shown in Table 4.1.3.

Table 4.1.3 Evaluations on Characteristics of Natural and Geographic Condition

Evaluation / Scale	1	2	3
Arrival of strong wave / cyclones	Low frequency	Medium	High frequency
Sediment Transport	Not strong	Medium	Strong
Effect of wave energy reduction	High(wide coral reef)	Medium	Low(narrow coral reef)

Source: JICA Expert Team

b. Reef Environment

The reef environment was evaluated on a scale of 1 to 3 from the characteristics shown in Table 4.1.4.

Table 4.1.4 Evaluations on Characteristics of Reef Environment

Evaluation / Scale	1	2	3
Cover degree* of coral	High (more than 50%)	Medium (10%-50%)	Low(less than 10%)
Water quality	Good	Medium (Within environmental limit of Mauritius)	Bad (Exceeds the environmental limit of Mauritius)

* Not applicable at freshwater inflow areas

Source: JICA Expert Team

c. Coastal Disaster

The coastal disaster was evaluated on a scale of 1 to 3 from the characteristics shown in Table 4.1.5.

Table 4.1.5 Evaluations on Condition of Coastal Disaster

Evaluation	1	2	3
Past coastal disaster	Not serious	Medium	Serious
Beach erosion / wave overtopping	Not serious	Medium	Serious

Source: JICA Expert Team

d. Coastal Utilization

The coastal utilization was evaluated on a scale of 1 to 3 from the characteristics shown in Table 4.1.6 and Table 4.1.4.

Table 4.1.6 Evaluations on Condition of Coastal Utilization

Evaluation	1	2	3
Frequency of use	Low	Medium	High (including tourism)
Properties along coast	Low	Medium	Large

Source: JICA Expert Team

With results of the basic study in Chapter 2 and evaluations of the 4 criterion above, 14 coasts were selected as priority coasts for preparation of the coastal conservation plan as shown in Table 4.1.7.

Table 4.1.7 Selection of Coasts for Preparation of Coastal Conservation Plan

No.	Name of Coast	Natural & Geographic Condition	Reef Environment	Coastal Disaster	Coastal Utilizaitio n	Average	Evaluatio n (>2)
1	Baie du Tombeau	3	1	2	1	1.8	
2	Pte. Aux Piments/Trou aux Biches/Mon Choisy	3	3	3	3	3.0	○
3	Bain Boeuf	2	2	1	2	1.8	
4	Cap Malheureux	2	1	1	2	1.5	
5	Poudre d'Or	2	3	1	1	1.8	
6	Roches Noires	2	2	2	1	1.8	
7	Bras d'Eau	2	2	2	1	1.8	
8	Belle Mare/Palmar/Trou d'Eau Douce	2	3	2	3	2.5	○
9	Ile aux Cerf	2	2	1	3	2.0	○
10	Grand River South East (GRSE)	1	3	1	2	1.8	
11	Grand Sable	1	2	2	3	2.0	●
12	Pte. d'Esny	3	1	3	3	2.5	○
13	Riamble/Saint Felix/Riviere des Galets	2	2	2	1	1.8	
14	Bel Ombre	2	3	2	2	2.3	○
15	Baie du Cap Public Beach	1	2	1	1	1.3	
16	Le Morne	2	3	2	3	2.5	○
17	La Preneuse/Tamarin/Flic en Flac	3	3	2	3	2.8	○
18	Albion (Beach)	3	3	3	2	2.8	○
19	Albion (Cliff)	1	-	-	-	1.0	●
20	Pte. aux Sables	3	3	2	2	2.5	○

Source: JICA Expert Team

◯ : Selected as eroded beach (more than 2.0 in average)
● : Selected in terms of cliff beach or wave overtopping

As described above, 14 coasts in total were selected; 1) 10 coasts with erosion problems on sandy beaches, 2) one coast with cliff erosion problems, and 3) one coast with wave overtopping problems on infrastructure. Two more coasts, Baie du Tombeau and Bras d'Eau were added from the request of MOESDDBM for the conservation plan.

- Ten coasts with erosion problems on sandy beach

・ Pte. aux Cannoniers (The Vale, No.B2-1)*
・ Mon Choisy (No.B2-5)
・ Q. Cocos Vge (No.B5-12), T. d'Eau Douce (No.B5-13)
・ Ile Cerfs (No.B6-1)
・ Pte. d'Esny (No.B7-2)
・ Bel Ombre (No.B9-2 & No.B9-3)
・ Le Morne (No.B10-1)
・ Flic en Flac (No.B11)
・ Albion (No.B12-1, No.B12-2 & No.B12-3: beach)
・ Pte. aux Sables (No.B13-2)

*Selected coast No.B2 is divided into Pte. aux Cannoniers (The Vale) and Mon Choisy in accordance with its geographical characteristics.

- One coast with erosion problems at cliff coast

・ Albion (cliff) (No.B20)

- One coast with a problem of wave overtopping impacting infrastructure in hinterland

- Grand Sable (No.B19)

➢ Two coasts from the request of MOESDDBM

- Bai du Tombeau (No.B1)
- Bras d'Eau (No.B1)

Source: Processed by JICA Expert Team based on the map of MOESDDBM

Figure 4.1.3 Fourteen Coasts for the Formulation of the Coastal Conservation Plan

4.2 Summary of Characteristics and Coastal Protection Measures for Priority Coasts

The problems, sediment budget and coastal condition, were summarized for the 14 priority coasts which were selected as the result of the section 4.1. Based on the obtained results of the basic study, the short and long term coastal conservation measures were examined. “Short-term measures” means that urgent countermeasures are required within several years as a target period of the project. On the other hand, “long-term measures” means measures that should be implemented over a timespan of ten years to several decades. The measures that still have experimental levels are also included in the long-term coastal conservation measures. These include coral plantation, improvement measures for water quality, etc. However, the monitoring and/or the pilot level project as an experimental field test might be required from this point even though full-scale implementation will be undertaken in the future. For such cases, the action plan will be presented in each coastal conservation plan.

The Mauritian side strongly requested a coastal conservation plan that includes all the individual coasts so that all necessary information for each coast is provided. Therefore the proposed coastal conservation plan for each coast is described in Volume 2 individually apart from this main report of Volume 1. Table 4.2.1 shows the summary for results of short and long term coastal conservation measures for each priority coast.

Table 4.2.1 Summary for Category of Coasts, Proposed Coastal Conservation Measures.

No	Coastal Names	Categorization of Problem	Sediment Budget			Category of Beach A: natural beach B: Structures (partial) C: Structures (many)	Recommended Measures	
			Total (1967-2012) (m3/45 year)	Yearly (m3/year)	Category I: Balanced II: Decrease III: Increase		Short Term Measures	Long Term Measures
1	Baie du Tombeau	Partial Erosion	17.700	390	I	B	Improvement of vertical structures	Setback
2a	Pte. aux Cannoniers (North)	Erosion	-2.400	-50	II	B	Periodical Nourishment + Improvement of revetment	Setback. Improvement of water quality
2b	Pte. aux Cannoniers (East)	Erosion	-8.600	-150	II	C	Nourishment with re-arrangement of groins	
3	Mon Choisy	Erosion	-22.400	-500	II	A	Periodical Nourishment	Improvement of Coral Reef Environment
4	Bras d'Eau	Partial Erosion	9.300	210	I	B	Sand recycle	Mangrove rehabilitation
5	Q. Cocos Vgie & T. d'Eau Douce	Partial Erosion	17.800	400	I	B	Sand recycle	Improvement of Coral Reef Environment
6	Ile aux Cerfs	Sedimentation	171.300	3.810	III	A	Sand extraction from landside + Sand recycle at partial eroded area	Integrated Sediment management. Improvement of water quality
7	Pointe d'Esny	Partial Erosion	17.800	390	I	C	Sand recycle with re-arrangement of groins	Setback. Coral preservation. Improvement of water quality
8	Bel Ombre	Partial Erosion	63.400	1.410	III	B	Setback (for illegal facility)	Coral Preservation
9	Le Morne	Partial Erosion	55.900	1.240	III	A	Sand bypassing	Coral Rehabilitation
10	Flic en Flac	Partial Erosion	23.800	530	I	A	Sand recycle	Improvement of Coral Reef Environment. Set back
11	Albion	Erosion	-7.700	-170	II	A	Setback (for new development) + nourishment	Coral Rehabilitation + Control of Fishing Activity. Set back
12	Pointe aux Sables	Partial Erosion	53.800	1.200	III	A	Sand recycle	Set back. Improvement of Coral Reef Environment
13	Grand Sable	Storm Surge	-	-	-	-	Gravel beach (Flexible Revetment)	Resettlement for the area faced on the coast
14	Albion (Cliff)	Cliff Erosion	-	-	-	-	-	Setback (Keep buffer zone)
	Total		373.500	8.300				

Source: JICA Expert Team

4.3 Planning Process with Stakeholders

In general, the coastal conservation plan should consider the following three functions:

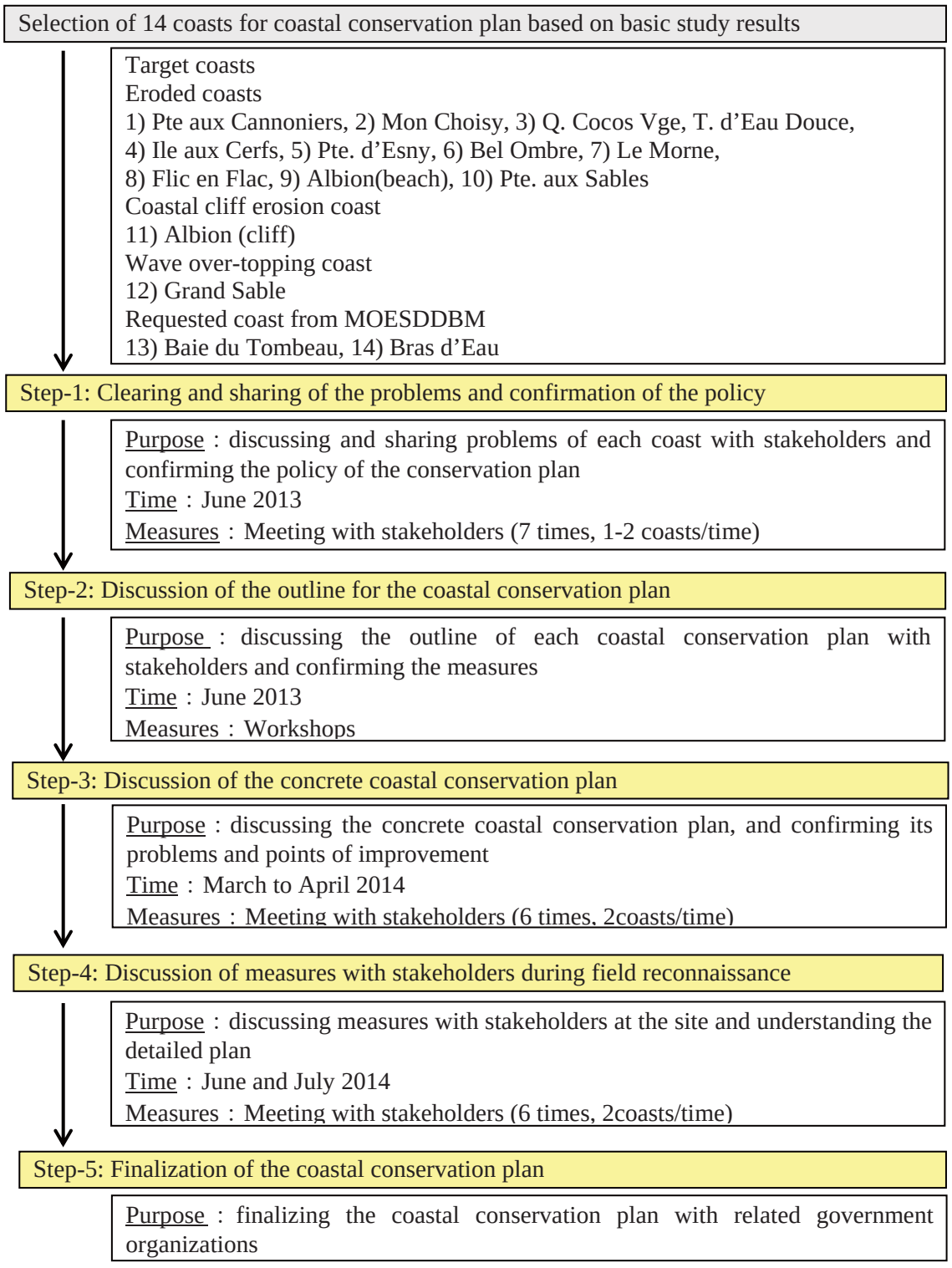
(1) Coastal protection: maintenance of sandy beaches and protection of assets such as houses, hotels and infrastructures such as roads along the coast

(2) Coastal use: promotion of coastal use such as swimming and recreational marine sports

(3) Coastal environment: conservation of natural environment which includes ecological diversity and land scape

The above requirements have a trade-off relationship. There is no universal conservation plan which can be applied to every coast because the requirement level is different according to the natural conditions and land use of each area.

It is important to formulate a plan after addressing the local problems and then basing it on the requirement levels of the three functions above. Thus, the policy for formulating the coastal conservation plan is to include the stakeholders and to consider the planning process for the capacity development. The planning process is shown in Figure 4.3.1 and Figure 4.3.2.



Source: JICA Expert Team

Figure 4.3.1 Outline of Planning Process with Stakeholders

Step-1: Stakeholders meeting for the clearing problems and the confirmation of the policy

Step-2: Workshop for the outline of coastal conservation plan

Step-3: Meeting with stakeholders for the concrete coastal conservation plan

Step-4: Discussion of measures with stakeholders during field reconnaissance

Source: JICA Expert Team

Figure 4.3.2 Outline of Planning Process with Stakeholders

4.4 Coastal Conservation Plan for Priority Coasts

The recommendations for conservation of 14 priority coasts are given below. The plans include the coastal protection plan, the reef conservation plan and the beach management plan for each coast as explained in Vol.2.

4.4.1 Baie du Tombeau

The beach is almost stable at present though it was eroded in the past. In the south, two sand bars were formed in the lagoon with an accreted beach. A part of the vertical revetments and trees were damaged though this was limited. The bridge at the north end to the public beach was damaged and it is difficult to access. The water quality is expected to improve as a result of prohibiting direct wastewater discharge. Also the coral is in relatively good condition. Taking all this into consideration, the recommendations are as follows:

- Improving vertical structures
- Maintaining a setback zone
- Repairing bridges
- Monitoring the shoreline and lagoon conditions
- Planting coral

4.4.2 Pte. aux Cannoniers

The beach at the north has been preserved except for a part that was lost and over half of the beach on the east side was lost because of the decrease of alongshore sediment supply. The vertical revetments in the setback area are probably the cause of the increase in beach erosion at the lease area, which is a large part of the coast. Those measures are not considered comprehensive for the stability of the whole beach and consensus among stakeholders, including residents is required. The hinterland has become a densely populated area. It is concerned that eutrophication due to domestic wastewater will progress and additionally the reef environment will deteriorate. With this in mind, the recommendations are as follows:

- Nourishing at the north and nourishing with groynes at the east
- Improving vertical structures
- Maintaining a setback zone
- Reaching a consensus of stakeholders and residents
- Improving the water quality

4.4.3 Mon Choisy

This beach shows long term erosion caused by a decrease of sediment supply. Other problems include erosion at the south, accretion at the north and the formation of beach scarps by cyclones. Further, the decrease of sand supply due to deterioration of water quality and coral reef conditions was presumed as one of the main causes of erosion. Thus, recovering the sand supply is required to improve the reef environment. There is a public beach at this site; management is required such as re-profiling and improvement of beach vegetation. Therefore, the recommendations are as follows:

- Nourishing and re-profiling
- Planting seagrass
- Regulating nautical activity
- Improving the water quality

- Implementing of beach management

4.4.4 Bras d'Eau

The coast is located at the north of the bay which has an opening to the east. A public beach, hotels, and bungalows are located along the coast. The beaches consist of coral sand and head lands of basalt. The sediment budget shows a deposition tendency. However, the change of the beach from erosion and accretion is relatively large due to the decrease of mangroves and seagrass together with alongshore sediment movement to the west. Also the existing vertical revetment has some impact on (namely is considered to contribute to) erosion. Beach scarp was seen in front of the toilets in the public beach. Thus, the recommendations are as follows:

- Maintaining a setback zone
- Reprofiling and sand recycling
- Removing vertical structures
- Relocating public toilets
- Planting mangroves and seagrass
- Implementing beach management

4.4.5 Q. Cocos Veg and T. d'Eau Douce

Large coastal changes of accretion and erosion are problems caused by the change of coral conditions in the reef together with the change of wave conditions. The vertical revetments and groynes constructed for erosion measures sometimes cause part of the erosion. The whole coast is accreting and the accretion is caused by the growth of a coral patch and erosion at the down drift side. The erosion has a tendency to recover but the coral is deteriorating. Accordingly, the recommendations are as follows:

- Maintaining a setback zone
- Improving vertical structures
- Monitoring the reef environment
- Conserving coral
- Implementing beach management

4.4.6 Ile aux Cerfs

The coast is located between two islands and includes a channel between them. Many tourists enjoy sunbathing on the white sandy beaches and playing in the current in the channel. In recent years, this channel has become closed because of sand sedimentation, causing beach use problems as well as erosion on adjacent beaches. The channel has been dredged but it has a tendency of closing up. The dredged sand can be uses as a source of beach nourishment. Therefore, the recommendations are as follows:

- Removing sand and bypassing from the channel
- Implementing beach monitoring
- Managing sand resources

4.4.7 Pte. d'Esny

Although the beach is accreting as a whole, a part of the beach has eroded. Alongshore sediment has moved from the eroded area to accreted areas. The existing vertical revetments and groynes are possibly contributing to the erosion. Also these structures are located in the setback area which ensures dynamic beach changes by cyclones. A large part of the coast is leased land so measures are taken by the individual lessees. When considering the stability of the whole beach, consensus of residents and stakeholders is required. Measures also need to conserve coral which contributes to the stability of the beach but is at risk of degradation due to climate change. Thus, the recommendations are as follows:

- Recycling sand
- Rearranging and removing groynes
- Maintaining a setback zone
- Reaching a consensus of stakeholders and residents
- Planting coral
- Improving the water quality

4.4.8 Bel Ombre

The coast is accreting as a whole and the eroded beach seems to be related with the disappearance of seagrass. At present, the erosion is not serious. However there are possibly several problems. These include the disappearance of seagrass and the impact of revetment and groynes constructed by hotels near the beach erosion. A part of the coastal houses located in low land areas have storm surge damage risks. Parasailing is popular in the lagoon and this possibly has an impact on the coral and seagrass. Accordingly, the recommendations are as follows:

- Maintaining a setback zone
- Relocating houses in the lowlands
- Regulating nautical activities

4.4.9 Le Morne

The coast is accreting and though the problems are limited at present, there are long term issues. These include the degradation of coral which is the source of sand, the change of coral and seagrass in the lagoon and the impact of climate change. The channel and jetty were constructed by the hotel owner and it blocks longshore sediment transport. The beach located north of the channel is experiencing erosion. The coral and seagrass conditions in the lagoon are possibly affected by large nets fishing and parasailing. Thus, the recommendations are as follows:

- Bypassing sand at the jetty
- Maintaining a setback zone
- Planting coral
- Establishing a marine protected area

- Regulating nautical activities

4.4.10 Flic en Flac

The beach at the center shows erosion though in total it is accreting. At the center, the lagoon is deeper than at other parts. This leads to beach erosion because the supplied sand deposits in the deeper parts do not reach the beach. In particular, due to high waves (from cyclones), beach scarps are noticeably easy to form. The coral is the source of sediment and long term measures are required. In particular, at the deep area in front of the eroded beach, planting coral is required to help the bed recover. First priorities will be the monitoring and analysis of the coral, seagrass and water quality. Thus, the recommendations are as follows:

- Recycling sand and re-profiling the beach
- Planting coral
- Regulating nautical activities
- Improving water quality

4.4.11 Albion (beach)

This beach has a tendency to erode as a whole and one of the causes is estimated to be the loss of seagrass bed in front of the beach. The scale of the coral reef is small. The forming of coral is poor because of the fresh water inflow of the river. The coral on the reef is easily impacted by environmental changes such as cyclones and floods. The loss of coral and seagrass is estimated to be caused by the increase of sea surface temperatures, the impact of cyclones, flooding and large nets fishing. Thus, the following are recommended:

- Maintaining a setback zone
- Planting seagrass
- Regulating nautical activities
- Planting coral

4.4.12 Pte. aux Sables

The coast is accreting as a whole. However, a part of the beach has been eroded, though accretion at the east side occurs from the alongshore sediment transport. Also, structures against erosion caused further erosion to the down drift side. The causes of this erosion may be the change of seaweed habitation on the reef, and the decrease of the sand supply from the reef due to coral environmental degradation. Also, the disappearance of the foreshore and promotion of erosion by the construction of the revetments and a slipway, which have been carried out after erosion, may be the causes of this erosion as well. In this coast, eutrophication which is caused by turbidity and waste water is advanced in comparison with other Mauritian coasts and the water quality has remarkably deteriorated. In addition, distribution levels of the coral on the reef has decreased when compared to the past, and the seaweed bed close to the central land is disappearing. With this in mind, the following is recommended:

- Recycling sand
- Maintaining a setback zone
- Improving vertical structures

- Improving the water quality
- Planting coral

4.4.13 Grand Sable

In terms of the terrain of the projected beach, both sides of the beach are formed by discharge of sediment from the rivers and in the middle it has weathered volcanic rock landforms and is eroded by waves. Since the impact of the coastal erosion is just escarpment degradation, the study found that there is no significant erosion problem on this beach. However, there will likely be overtopping problems because the coastal road, which is considered the primary road from the airport to the southeast tourism area, is established on low elevated land. Accordingly, a flexible revetment was planned and a part of this was implemented. Additionally, trash and seagrass have accumulated on the beach and have caused environmental problems. Therefore, the following measures are recommended:

- Extending the flexible revetment
- Implementing beach management of seagrass

4.4.14 Albion (cliff)

The cliff coast of Albion was selected as the representative coast of cliff erosion. The measures for cliff coasts are mainly utilizing the setback and protecting the cliff base by structures. The setback is adequate because of its cost and applicability for future change. The method to estimate the setback limit is proposed.

- Maintaining a setback zone

Chapter 5

Beach Management Plan

5 Beach Management Plan

The beach management plan consists mainly of the following:

1) Problems and issues which beach management at priority coasts (14 beaches) are presently facing.

2) Proposals for improving beach operation and management, land use management and beach use management based on the issues described above.

3) A beach management plan and future issues, especially beach nourishment, which includes sand recycling and sand bypassing as described in the beach conservation plan in Chapter 4, particularly from the point of view of integrated sand management.

This chapter consists of the following:

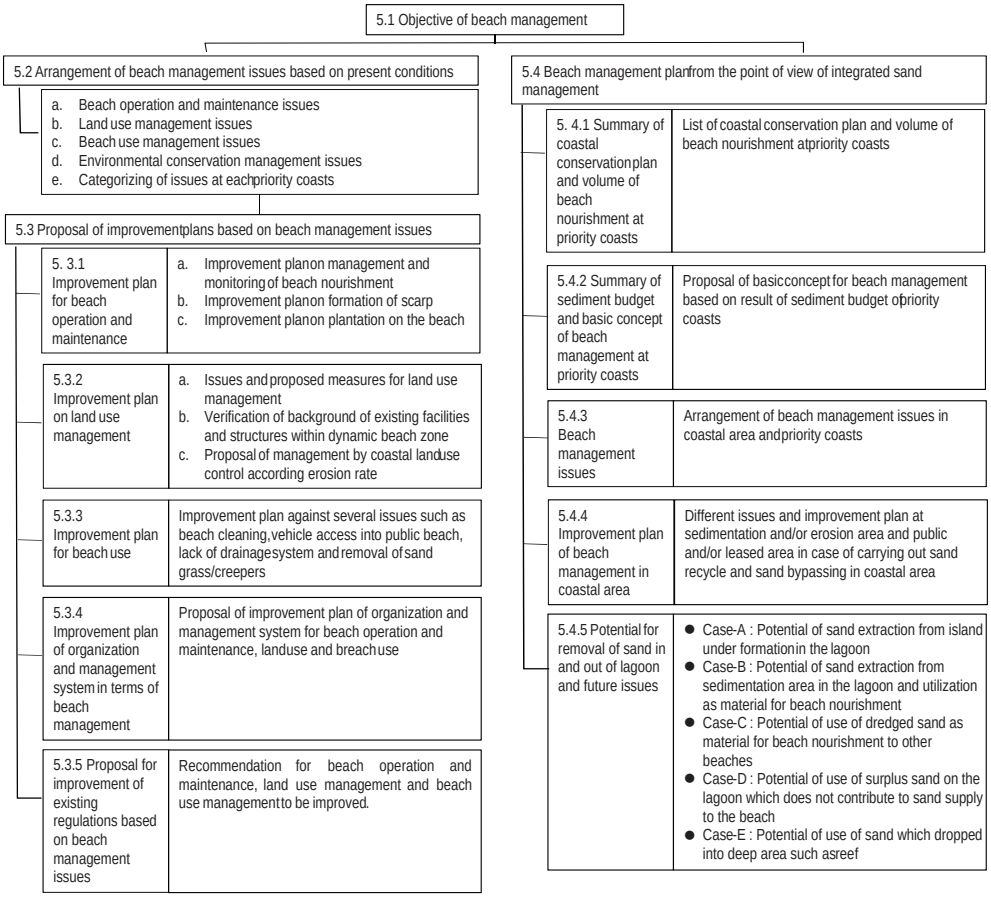
5.1 Objective of beach management

5.2 Beach management issues considering present conditions

5.3 Improvement plans based on beach management issues

5.4 Beach management plan based on concept of integrated sand management

In addition, the whole structure and content of this chapter are summarized as follows.



Source: JICA Expert Team

Figure 5.1.1 Summary of Contents for Discussion on Beach Management

5.1 Objective of Beach Management

Beach management must be carried out effectively utilizing resources, space and beach conservation because a lot of people live and/or spend time in coastal areas. These people engage in various activities and are competing with others for coastal utilization. The current state of beach management in Mauritius is generally good. However, careful observation from the viewpoint of beach use, environment, erosion measures, landscaping and so on reveals aspects of each that need to improve

The objective of beach management described in this chapter is to reflect on past beach management plans and consider improvement plans for various issues at priority coasts from the following points of view: 1) Beach operation and management, 2) Land use management, 3) Beach use management, and 4) Environmental conservation management in accordance with site reconnaissance survey, review and study of existing data and information. Environmental conservation management is described in Chapter 6 (Reef Environmental Conservation) in detail.

Areas of beach space management for this study cover estuaries of candidate beaches, beaches and their hinterland, and coral reefs. Specific content required from the above four management items are summarized below. Keeping these management items in mind, improvement plans are shown after extraction of specific issues in consideration of the present conditions of each target beach.

Table 5.1.1 Summary of Items and Contents for Beach Space Management

Management Items	Contents of Management
Beach Management and maintenance	• Monitoring and maintaining beach profile • Monitoring and maintaining existing offshore beach protection facilities (groynes, revetments, amongst others.) • Planning, designing and construction of new offshore beach protection facilities • Monitoring and maintenance of existing onshore public beach facilities (parking, street lights, benches, walkways, amongst others.) • Planning, designing and construction of new onshore public beach facilities • EIA requirement for above implementation works, if any • Building consensus regarding construction of facilities and countermeasures against erosion
Land Use Management	• Controlling the position of the setback line (30m from HWM) • Monitoring and controlling any construction/structures within the setback line • Updating and renewal of setback line • Setting up suitable setback line under various conditions • Monitoring felling of trees including mangroves
Beach Use Management	• Monitoring and control of activities at public beaches • Cleaning up garbage and driftage • Considering restrictions on removal of corals/seagrass and seaweeds from the beach
Environmental Conservation Management	• Monitoring and conservation of coral reef and associated ecosystems (mangroves, seagrass, wetlands) • Controlling water pollution • Maintaining and restoring coastal vegetation • Managing coastal landscapes • Enforcing laws • Raising awareness

Source: JICA Expert Team

5.2 Arrangement of Beach Management Issues based on Present Conditions

In accordance with various beach management issues of priority coasts as described in Supporting Report_Chapter-3, each problem on beach management and maintenance, land use management and beach use management of the 14 beaches is summarized and classified in Table 5.2.1

1) Beach Management and maintenance

- Maintenance and monitoring of beach nourishment
- Formation of scarps
- Plantation on the beach

2) Land Use Management

- Existing coastal facilities
- Coastal area dredging
- Existing facilities and structures within dynamic beach zone (Inc. setback area)
- New construction of structures within dynamic beach zone (Inc. setback area)

3) Beach Use Management

- Public beach cleaning
- Vehicle access on public beach
- Lack of drainage systems
- Removal of grass growing on beach

As a result, several issues were pointed out as follows: In terms of beach management and maintenance, various issues such as maintenance, management and monitoring of beach nourishment, inappropriate trees within the dynamic beach zone, and so on were found at public beaches. Various issues on land use were found at leased land such as hotels and cottage sites . One beach use issue is beach cleaning .The same was also found at public beaches, namely, disposal of sand along with drift seaweed, vehicle access into the beach and poor drainage systems at the beach. While keeping in mind the above issues, improvement plans were proposed in the next section.

Table 5.2.1 Classifying in Patterns of Beach Management Issues

No.	Name of Beach	Priority	Beach Operation and Maintenance			Land Use Management				Beach Use Management			
			Maintenance and monitoring for beach nourishment	Formation of scrap	Plantation on the beach	Existing coastal facilities	Dreading in coastal area	Existing facilities and structures within dynamic beach zone(Inc. Set back area)	New construction of structure dynamic beach zone (Inc. set back area)	Beach cleaning	Vehicle access on public beach	Lack of drainage system	Removal of sand grass/creepers
1	Baie du Tombeau					● (Revetment)							
2	Pte. Aux Cannoniers			●		● (Revetment, groin)		● (Slipway)		●			
3	Mon Choisy	Priority beach	●	●	●	● (Revetment)				●	●		
4	Bras D'Eau			●		● (Revetment)				●			
5	T. d'Eau Douce					● (Revetment, groin, offshore breakwater)		● (Slipway)		●			
6	Ile aux Cerfs	Priority beach	●	●		● (Groin)							
7	Pte. D'Esny（Blue Bay)	Priority beach	●	●	●	● (Revetment, groin)			● (Revetment)				●
8	Bel Ombre	Priority beach				● (Revetment, groin, offshore breakwater)		● (Restaurant)					
9	Le Morne			●	● ●	● (Training wall)	● (In channel)	● (Restaurant)			●	●	
10	Flic en Flac	Priority beach	●	●	● ●			● (Hotel, flowerbed, parasol, etc.)		●	●		
11	Albion			●		● (Revetment)				●	●	● (Garbage in drain)	
12	Pte. Aux Sable	Priority beach		●		● ● (Revetment)				●			
13	Grand Sable	Priority beach								●		●	
14	Albion (Cliff)					-		-		-	-	-	-

Remarks
●: Issues in public beach
●: Issues in leased area such as hotel, houses, etc.

Source: JICA Expert Team

5.3 Proposal of Improvement Plans based on Beach Management Issues

5.3.1 Improvement Plans for Beach Management and Maintenance

Improvement plans for beach management and maintenance about issues of 1) Management and monitoring of beach nourishment, 2) Scarp forming and 3) Planting at the beach are shown as follows:

a. Improvement Plan on Management and Monitoring of Beach Nourishment

a.1 Issues of Beach Nourishment

As previously mentioned, the following are pointed out as issues relating to managing and monitoring beach nourishment.

- The slope of the profiled beach was steep. As a result, it was difficult to access the beach. (Mon Choisy)

- Sand recycling that moves accumulated sand to erosion areas has been carried out at a channel between islands. But the monitoring is insufficient after sand recycling. In addition, there is some possibility that the determination of shape of beach nourishment and its management were not conducted sufficiently. (Ile aux Cerfs)

- Removal of existing revetments and beach nourishment work were carried out to improve the coastal environment on the south east of Blue Bay in 2012. The slope of the beach is still steep, 1: 2.6 on average (1:1.7 to 1:3.8) in spite of a planned shape of 1:6. These areas are leased sites and are used by lessees and fishers who walk along the beach. (Pte. d'Esny, Blue Bay)

The common points of each issue are pointed out as follows:

- Scarps were formed after beach nourishment, and the foreshore shape after beach nourishment was very different from the shape of the existing beach. These are obstacles to beach use and landscaping.

- Foreshore (beach profile) leveling work during beach nourishment was not conducted adequately; project management and quality control during and after the work is considered to have been insufficient.

- It is difficult to evaluate the outflow of sand and change of shape after beach nourishment because periodic monitoring has not been carried out after beach nourishment work.

a.2 Improvement Plan on Management and Monitoring of Beach Nourishment

It is necessary to take notice of the following points in case beach nourishment is carried out using sand from sand pits on land, or sand at accumulated areas is transported to eroded areas as sand recycling or sand bypassing. The sand nourishment work is mentioned in Section 5.4 (Beach Management Plan) from the point of view of integrated sand management in detail.

- If beach nourishment is carried out at an eroded area, a suitable foreshore slope and backshore crown height should be set based on survey results of beach profiling before execution of construction works on the site. The shape of beach nourishment should be as close as possible to the existing beach profile to control drastic profile

changes and outflow of sand after beach nourishment.

- The grain size of existing sand in and around the construction site should be checked and it is necessary to compare and evaluate the material between the existing sand and the sand being procured for beach nourishment. An equal or bigger grain size than that of the existing beach is desirable to minimise sand loss from the profiled (nourished) beach.

- Supplied sand transported into the eroded area should be leveled according to the planning profile and a beach profile survey should be carried out immediately after beach nourishment. It is necessary to confirm whether it meets the specifications or not.

- The frequency of monitoring should be once a month after nourishment for the first monitoring and about every three months from the second monitoring. The frequency can be changed after confirming a stable beach profile. High frequency should be kept in mind for the first three months after beach nourishment because beach profile changes drastically during that period. The monitoring data can be referred to the next beach nourishment plan and beach management plan.

b. Improvement Plan on Formation of Scarps

b.1 Formation of Scarp Issues

As previously mentioned, formation of scarp issues were pointed out as follows.

- A scarp of more than 2 meters in height was formed at the place where sand was nourished and steps were installed there in order to access the beach. In addition, a scarp of tens of centimeters in height also exists in other areas outside the beach nourishment area and the roots of high trees are exposed in this area (Mon Choisy). A scarp of about one meter in height was formed after beach nourishment (Blue Bay).

- Scarps of tens of centimeter high were formed where leased lands and public beaches meet (Pte. aux Cannoniers, Ile aux Cerfs, Le Morne, Flic en Flac, Pte. aux Sables). These occur mostly after heavy rainfall or heavy swells/ cyclone events.

- Large scarp is formed in front of the AFRC. There is some possibility that trees and fences will fall down and be washed away due to erosion. This scarp is due to the presence of a concrete drain and also due to degradation of the coral reefs and seagrass in the lagoon of Albion. (Albion) .

The common points for each issue as mentioned above are pointed out as follows:

- Scarps indicate erosion tendencies. But both the area and height of scarps have been increasing due to being left alone for a long time.

b.2 Improvement Plan of Formation of Scarp

It is necessary to consider the following points about the formation of scarps.

- It is important to grasp shoreline changes and scarp forming as early as possible by carrying out periodic monitoring. In public beaches, beach cleaning contractors have an obligation under their contract to deal with scarps on beaches following heavy

rainfall and storms / cyclone events. Therefore, during the daily maintenance of the beach, beach cleaning contractors should fill in any scarps that have formed after rainfall/storms/cyclone events as soon as possible. In addition, the concerned authorities shall maintain continuous monitoring of the beach profile state after extreme weather events.

- Planting grass/creepers/bushes on top of the beach berm would help reduce the impact of rainfall and waves on sediment movement out of the beach.

c. Improvement Plan on Vegetation on the Beach

c.1 Coastal Vegetation Issues

As previously mentioned, vegetation issues were pointed out as follows:

- High trees, especially, Casuarina, exist at foreshore and backshore in the public beach. These trees cause beach erosion and the formation of scarps.

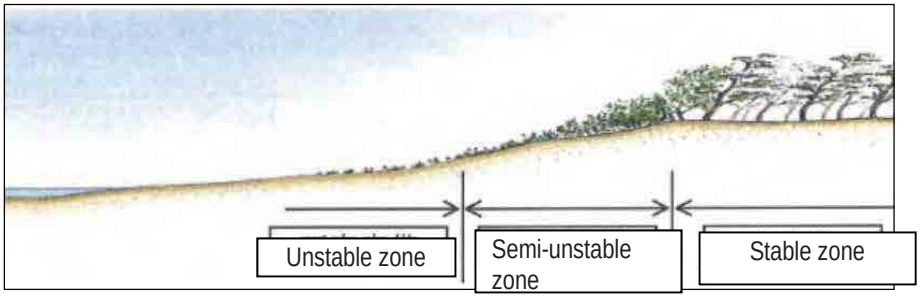
c.2 Improvement Plan for Coastal Vegetation

Main functions of the coastal vegetation are as follows.

- It adds value to the scenic beauty of the coastal landscape
- The substratum vegetation such as grass and bushes help in sand retention. In addition, sub canopy trees and high trees have a function to minimise the impact of wind-blown sand, salt spray and act as a wind breaker .

As mentioned above, the following points are proposed for the beach vegetation

- A suitable arrangement and composition of beach vegetation is recommended in order to improve the coastal landscape and utilization and to make use of the above-mentioned functions. It is also recommended that the plants are arranged in order of height succession starting with grass and creepers followed by bushes and trees.
- High trees with hard, extensive roots such as casuarina trees should not be planted in either the unstable foreshore zone or the semi-unstable backshore zone considering wave run-up and natural vegetation. Setting up a suitable planning zone is required.
- Casuarina, which is a non-native species, were planted in the public beach as it was fast growing. However, it is favorable that native species be selected as much as possible at each zone based on the current situation of the beach which has natural condition in Mauritius like at La Prairie at the south part of the country. It is also necessary to consider the recommendations of the Forestry services when selecting a suitable species.



Source: Procedure for coastal works with environmental symbolic type

Figure 5.3.1 Zonation of Beach Vegetation

Source: JICA Expert Team

Figure 5.3.2 Natural Vegetation at La Prairie in the South of Mauritius

5.3.2 Improvement Plan on Land Use Management

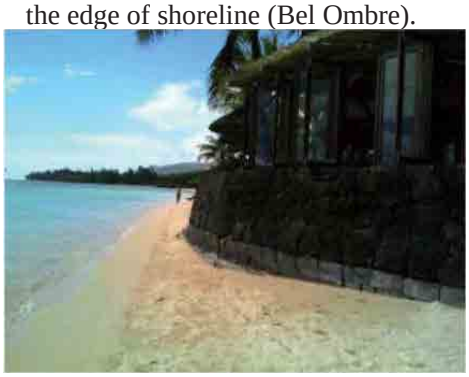
a. Issues and Proposed Measures for Land Use Management

Land use issues consist of 1) Existing coastal structures, 2) Dredging at coastal area, 3) Existing facilities and structures within the dynamic beach zone including the setback area, and 4) Construction of new facilities and structures within the dynamic beach zone including the setback area. These issues and their improvement plans are shown as follows:

Table 5.3.1 Problems and Proposed Measures of Land Use Management

	Specific problems	Proposed measures
Existing coastal facilities	●Sandy beach does not exist in front of the vertical revetment. Sand deposits on either side of the revetment. It seems that sand has not accumulated in front of the revetment due to reflective waves. (Pte. aux Cannoniers, T. d'Eau Douce, Pte. d'Esny)	● It seems that vertical revetment makes reflected waves larger and these waves have caused erosion in and around the revetment. In order to reduce the reflective waves while keeping the utilization and landscape in perspective, a setback or review of the revetment structure is required. ● It is very difficult to gain acceptance for setting a setback with lessees because they have already made a contract for the leased land for 60 years until 2068 and they have houses within the dynamic beach zone.

	Specific problems	Proposed measures
		Therefore, it seems that the modification of revetment from a vertical type to a sloping permeable type with vegetation (if possible) is a suitable measure in order to reduce reflective waves and to improve access and landscape.
	● At Trou d'Eau Douce, many groynes made with gabions and sandbags are constructed in areas of erosion. Erosion is ongoing at the down-drift of this area. It is assumed that groynes have been constructed from up-drift to down-drift in turn considering the situation of erosion and accumulation. These groynes are blots on the coral reef landscape. ● A lot of groynes were constructed at every house, leisure home and hotel properties based on the self-judgment of leaseholders. As a result, there are some cases such as a retreating shoreline and complete disappearance of sandy beach due to ongoing erosion after construction of groynes. In addition, there are cases where relations between neighbors have soured over groynes (Pointe d'Esny) . ● Bel Ombre: Some groynes made of natural stone were constructed in front of the hotels. Erosion is ongoing on the down-drift side of groynes.	● Many of the existing groynes were constructed by self-judgment and at the lessees own cost before establishment of EIA licensing. Therefore, it is difficult to compel them to demolish existing facilities on the beach. ● The existing facilities can be categorized into three patterns such as 1) effective, 2) not effective and 3) furthering erosion in and around the facilities themselves. It is important to build a consensus with lessees and stakeholders about demolition or modification of facilities in case of 2) and 3) as mentioned above after showing the effects and impact of existing facilities. ● In terms of cost allocation, there is a possibility of following two cases, that is, 1) lessee (him or herself alone), 2) lessees and neighbors. It is important to have discussions and build a consensus because establishment of new regulations and rules are required.
Dredging at coastal area	● The dredging work is carried out for pleasure boats in the channel between hotels in the north of Le Morne. The dredged material is stocked on the beach. The erosion occurs on the north side of the channel.	● Periodic monitoring should be carried out by the hotel side. But it is recommended that the hotel submits the result of monitoring to MOESDDBM after dredging. MOESDDBM should then evaluate whether the method of beach management is appropriate.

	Specific problems	Proposed measures
Existing facilities and structures in dynamic beach zone (Inc. setback area)	●At Pointe d'Esny, sand has accumulated in the northern side. During lease renewals in 2008, most of the leases were renewed with the limits of HWM from 1968, except for four cases where the new leases have been extended to the new HWM. ●However, the boundaries of the lessees are not clear on site, and some of the lessees are claiming that their property extends up to the new HWM by placing private property signboards. 	●Following a recommendation made by the ICZM Committee in 2013 that sand accumulated areas shall not be leased; the MHL is no longer leasing these sites. Sites where leases have been extended up to new HWM were processed before 2013. It should be noted that in cases where leases are extended, the rental for the PG land also increases. ●The accumulated sand should be used for public purpose because the sand is supplied from erosion areas of the up-drift side. It is important to maintain the beach continually with stable conditions by clarifying the boundary between public and private land and to transport and dump sand from the accumulated area to the eroded area periodically as a sand recycling system. The future issues are to set up rules for consensus building and cost allocation among lessees and related institutions in individual leased land areas.
	●Restaurants of some hotels project to the edge of shoreline (Bel Ombre). 	●As there is a possibility that restaurants will incur damage and cause erosion on the down-drift coastline, it is necessary to demolish some of the existing facilities and set back systematically. It is also necessary to evaluate the necessity of demolition and relocation by verifying the location and construction date of existing facilities and structures based on previous aerial and satellite photographs. ●It is recommended that regular inspection for construction within the coastal zone be carried out by MHL, MOESDDBM and District Council (DC).
	●Some beach umbrellas with foundation are put at the edge of shoreline. ●Trees exist on the foreshore in front of the hotels. (Le Morne, Flic en Flac)	●It is acceptable to place removable structures beyond 15 m from HWM, as per (Policy Planning Guideline) PPG provisions. But trees and beach umbrellas with a base should not be put within the dynamic beach zone because there is the possibility that they will interfere with hydrodynamics and may induce beach erosion. Enforcement of the

	Specific problems	Proposed measures
		PPG by the DC and MHL is strongly recommended at lease sites while the Beach Authority is recommended to enforce the PPG at public beaches.
	●A hotel has been constructed at the erosion area on the south of the beach. (Le Morne) 	●With the construction of hotels and houses along the coast at the erosion area, not only the regulation of a setback line (30 m from HWM) but also clearance space should be considered, assuming an erosion rate and effects of sea level rises in the future. ●It is necessary to consider clearance width depending on erosion rate based on the shoreline change analysis. If new facilities and buildings are constructed behind the beach at eroded areas, it is recommended that the building be located further back than the set back line that is 30 m from HWM.
	●Albion: There is a plan to construct a hotel on the north side of the AFRC and a wetland exists behind the planned construction site. The construction works have a possibility of exerting a great influence on the wetland. There is concern that this will have an effect on coral due to the changes of sediment flow patterns and inflow of freshwater from the river.	●It is necessary to pay attention to the impact on wetlands by construction /development within the buffer areas because wetlands function as a balancing reservoir to regulate floods and purify water before it is discharged into the sea. This improves the water quality in the lagoon and protects the coral reefs
Construction of new facilities and structures in dynamic beach zone (Inc. setback area)	●The space from HWM to the new villa under construction is kept more than 30 m from Pte. d'Esny. But a new retaining wall was constructed in front of the new villa. The retaining wall is an unacceptable structure because the distance from HWM is less than 10 m. 	●The MHL gives planning clearance for construction on leased sites. Following the Planning clearance, a Building and Land Use Permit is issued by the District Council. ●However, there is inadequate monitoring at the MHL and DC. In this respect, it is proposed that an Enforcement unit be set up at MHL and DC to monitor construction within the dynamic beach zone, including the setback area.

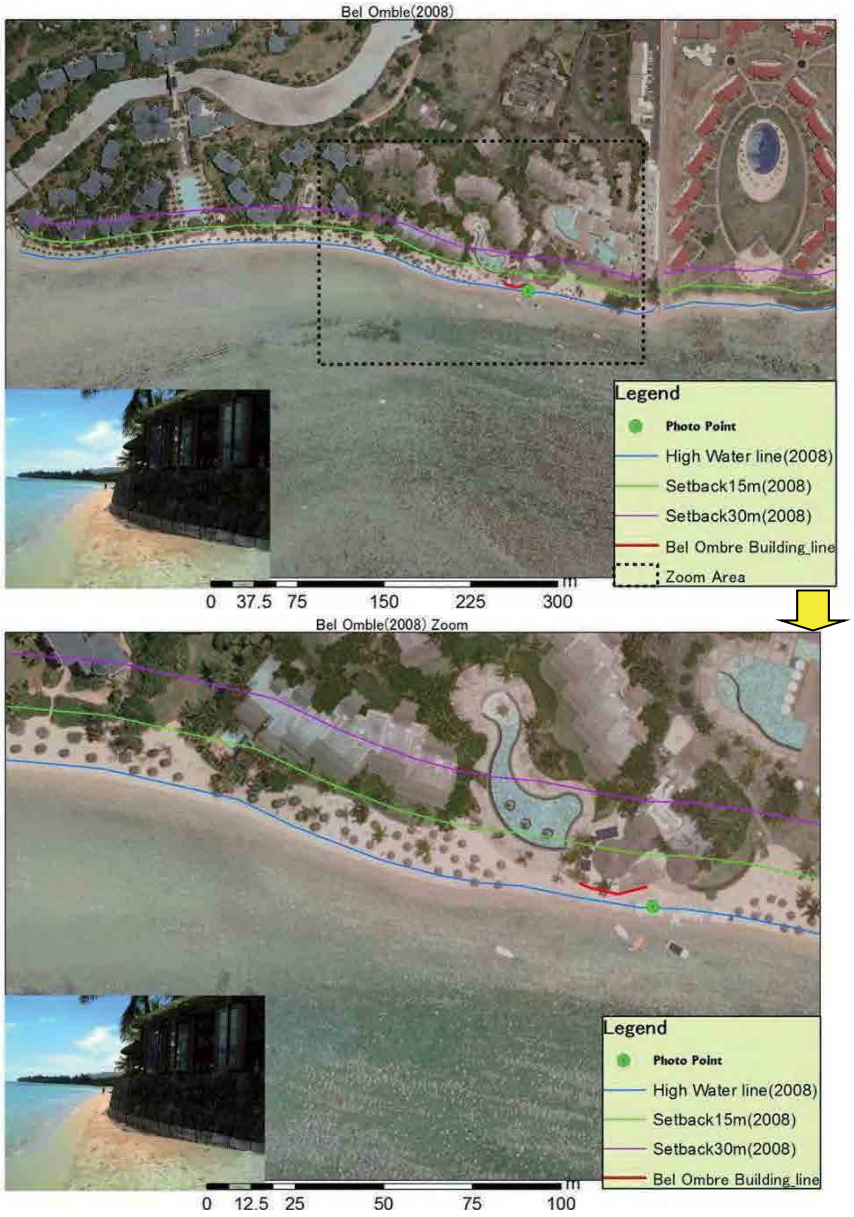
Source: JICA Expert Team

b. Verification of Background of Existing Facilities and Structures within the Dynamic Beach Zone

In terms of existing facilities and structures within the dynamic beach zone, existence of construction and removable structures and permanent structures close to sea within the dynamic beach zone should be verified at places where some issues were pointed out as mentioned above based on background information from aerial and satellite photographs.

b.1 Bel Ombre (Hotel Heritage Awali : Restaurant)

Hotel Heritage Awali exists on this beach and the restaurant run by this hotel is located close to the shoreline in front of the hotel. There is almost no foreshore remaining in front of the restaurant. The positional relation between the restaurant and setback line is verified based on previous aerial and satellite photographs. Although the restaurant is not in aerial and satellite photographs from 1997 to 2000, it can be seen in satellite photograph in 2008. A line for HWM was put on a 2008 satellite photograph. Then, with the HWM line being used as a starting point, lines for 15 m and 30 m from the HWM were added on the land side. The result proves that the restaurant and a part of the swimming pool are located between the HWM and the 15m setback line . On the other hand, several guest rooms are located landward of the 15m setback line. It seems that the restaurant and swimming pool were constructed without planning clearances from MHL. If hotel facilities were constructed after 2004, the facilities, not only the restaurant and swimming pool, but also guest rooms did not follow the setback rule because the setback rule was changed from 15 m to 30 m from the HWM in 2004 and guest rooms are located within the 30 m setback area. It is necessary to demolish or relocate these facilities through discussions between the hotel management and related institutions after checking the construction year and date of approval of EIA for every structure.



Source: JICA Expert Team

Figure 5.3.3 Verification of Positional Relation between Hotel Facilities and Setback Lines (Bel Ombre)

b.2 Flic en Flac: Hotel Hilton

A part of the walkway at the Hilton hotel exists in front of the hotel on the beach. This structure was not in aerial photographs until 2000 but it can be seen in a satellite photograph in 2004. A line for HWM was put on the satellite photograph in 2004 and then from the HWM line as a starting point, lines with 15 m and 30 m from the HWM were added on the landward side of the HWM. The result proves that this structure is located between the HWM and the 15m setback line. There is a possibility that this was constructed without observing the setback rule. It is necessary to demolish or relocate this deck through discussion between hotel management and related institutions because this structure will block continuous sediment transport in and around the hotel in the future.

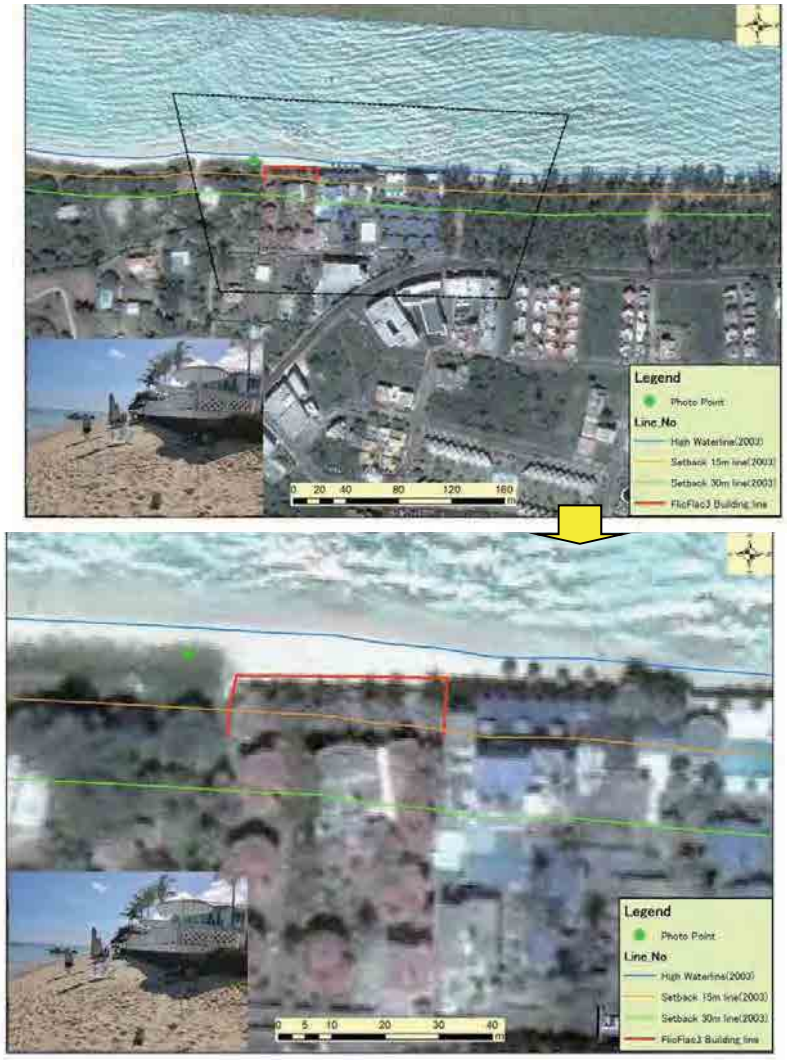
Source: JICA Expert Team

Figure 5.3.4 Verification of Positional Relation between Hotel Facilities and Setback Line (Flic en Flac-1)

b.3 Flic en Flac: Gold Beach Hotel

A concrete deck exists in front of the Gold Beach Hotel as well as the Hilton Hotel as mentioned above. This deck was not in aerial photographs until 2000, but it can be seen in satellite photographs from 2003. An HWM line was put on the satellite photograph in 2003 and then from the HWM line as a starting point, lines with 15 m and 30 m from the HWM were added on the landward side. The result proves that this deck is located between the HWM and the 15m setback line. In addition, a part of the hotel facilities and swimming pool are also included in this area. There is a possibility that this deck was constructed without observing the setback rule. It is necessary to demolish or relocate this deck through

discussions between the hotel management and related institutions because this will block continuous sediment transport in and around the hotel in the future. Given that the site is already developed and setback cannot be enforced, it may be recommended that the impermeable retaining wall be modified into a sloping and permeable retaining wall.



Source: JICA Expert Team

Figure 5.3.5 Verification of Positional Relation between Hotel Facilities and Setback Line (Flic en Flac-2)

c. Proposal of Management by Coastal Land Use Control According to Erosion Rate

Three classifications, namely, 1) Erosion area, 2) Potential risk area of erosion and 3) Accretion area are set up in accordance with calculation results of the erosion rate of each candidate beach based on interpretation of aerial and satellite photographs of the past.

- Erosion area: Erosion rate of shoreline is more than 15 cm per year
- Potential risk area: Amount of shoreline change is between -14 cm and + 14 cm per year. Considering seawater rises and change of wave patterns in the future, it is possible these areas can turn into erosion areas.
- Accretion area: Rate of shoreline expansion is more than 15 cm per year.

Table 5.3.2 shows an example of a land-use regulation plan. In this table, pink, yellow and white colors show the erosion area, the potential risk area and the accretion area respectively. In the next section, the classification map for regulation of land use at each priority coast is shown using current conditions and issues. These areas should take the following into consideration:

- Erosion area: It is necessary to take measures against erosion as early as possible.
- Potential risk area: It is necessary to review and re-set the setback line in developed properties at the time of renewal. On the other hand, it is necessary to consider keeping 5 to 10 m as a clearance zone from the setback line and to set up rules on use between the HWM and the setback line in undeveloped property.
- Accretion area: This area should be managed in accordance with existing institutions.

It is proposed that the regulation plan and classification map of land use should be reviewed and renewed at least every five years in order to carry out suitable land-use management.

Table 5.3.2 List of Erosion, Erosion Risk and Accretion Areas

Cell No.	Sub-cell No.	Erosion speed (m/Year)	Name of beach
1	1-1	0.05	Baie du Tombeau
	1-2	-0.06	
	1-3	0.00	
	1-4	0.32	
2	2-1	-0.16	The Valle
	2-2	0.10	
	2-3	0.00	Mon Choisy
	2-4	0.00	
	2-5	-0.08	
	2-6	0.02	
	2-7	-0.23	
	2-8	-0.10	Trou aux Biches
	2-9	-0.09	
	2-10	-0.02	Pointe aux Piments
	2-11	0.08	
	2-12	0.00	
	2-13	-0.17	
	2-14	-0.09	
	2-15	0.24	
	2-16	0.10	
3	3-1	0.08	Roches Noires
	3-2	-0.11	
	3-3	-0.06	
	3-4	-0.09	
	3-5	0.00	
	3-6	0.05	
4	4-1	0.01	Bras d' Eau
	4-2	0.12	
	4-3	-0.20	P.G. Choisy
	4-4	-0.28	
	4-5	0.76	
5	5-1	0.07	Belle Mare
	5-2	0.48	
	5-3	0.03	
	5-4	-0.06	

Cell No.	Sub-cell No.	Erosion speed (m/Year)	Name of beach
5	5-5	0.19	Palmar
	5-6	0.12	
	5-7	-0.02	
	5-8	-0.08	
	5-9	0.01	
	5-10	0.12	
	5-11	1.06	Q. Cocos Vge
	5-12	-0.41	
	5-13	-0.16	T. d'Eau Douce
	5-14	0.27	
	5-15	-0.08	
6	6-1	-0.15	Ile aux Cerfs
	6-2	0.51	
	6-3	0.71	
	6-5	-0.20	
	6-6	-0.18	
	6-7	-0.04	
7	7-1	0.40	Pointe d' Esny
	7-2	-0.31	
	7-3	-0.10	
	7-4	0.11	
	7-5	0.12	
	7-6	0.23	
	7-7	0.27	
	7-8	0.40	
8	8-1	-0.02	Blue Bay
	8-2	0.59	
	8-3	0.06	
	8-4	0.03	Saint Felix
	8-5	-0.23	
	8-6	0.05	
	8-7	0.06	
9	9-1	0.16	Bel Ombre
	9-2	0.25	
	9-3	-0.02	
	9-4	-0.13	
	9-5	0.10	

Cell No.	Sub-cell No.	Erosion speed (m/Year)	Name of beach
10	10-1	-0.25	P.G. Le Morne
	10-2	0.41	
	10-3	0.08	
	10-4	0.15	
	10-5	-0.20	
	10-6	0.49	
	10-7	0.06	
11	11-1	0.46	Flic en Flac
	11-2	-0.29	
	11-3	0.13	
	11-4	-0.03	
	11-5	-0.22	
	11-6	0.55	Tamarin
	11-7	-0.09	
	11-8	0.10	
	11-9	0.12	
	11-10	-0.04	La Preneuse
	11-11	0.03	
	11-12	0.03	
	11-13	-0.05	
12	12-1	0.02	P.G. Albion
	12-2	-0.10	
	12-3	0.01	
	12-4	-0.18	
	12-5	0.16	
13	13-1	0.20	Pointe aux Sables
	13-2	-0.40	
	13-3	-0.04	
	13-4	0.59	
	13-5	0.04	
	13-6	0.03	
14	1	0.00	Pte. Aux Cannoniers
	2	0.00	
	3	0.10	
	4	-0.16	
	5	-0.10	
	6	-0.16	
	7	-0.03	
	8	0.04	

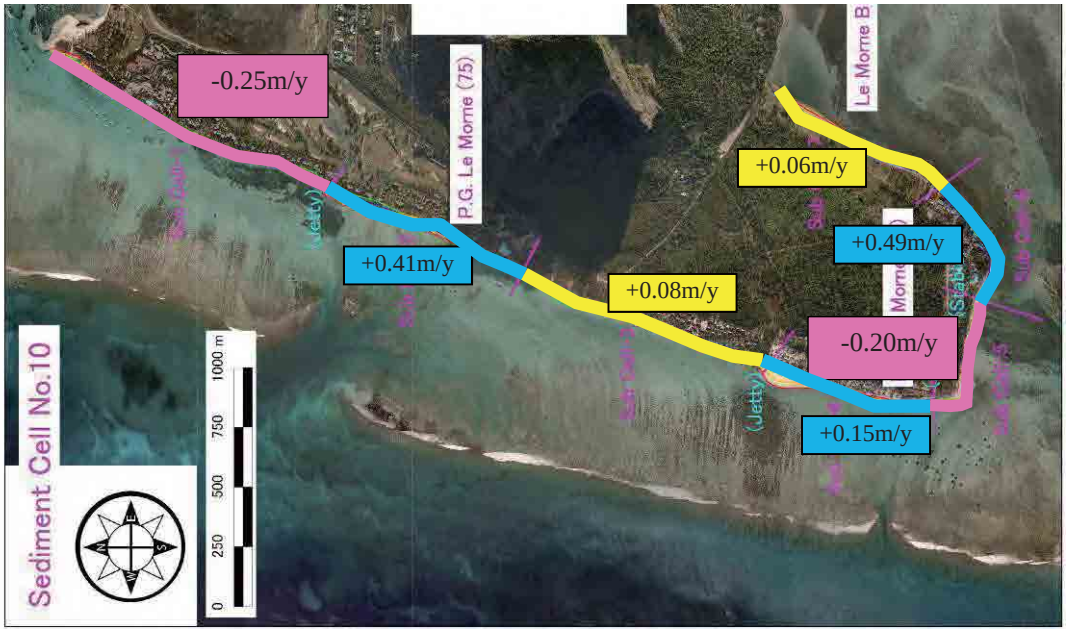
Legend:

Less than -0.15 m/y	: Required countermeasures
+0.14 - -0.14m/y	: Required regulation of land use
Morethan +0.15m/y	: Accumulated area

Source：JICA Expert Team

Figure 5.3.6 is a draft land use map showing possible land use regulations for this beach according to the above concept. In this figure, the pink line, the yellow line and the blue line shows the area of erosion, the area of potential erosion risk, and the area of accretion respectively. The erosion area and the accumulation area are intermixed at this beach. The

beach consists of potential risk areas (+0.06 and +0.08 m/y) at Sub-cell-3 and 7 and erosion areas (-0.20 and -0.25 m/s) at Sub-cell-1 and 5. It is necessary to continuously monitor and understand erosion tendencies at potential risk areas and to implement the short-term and mid-and- long term conservation measures at erosion areas.



Source：JICA Expert Team

Figure 5.3.6 Classification Map of Regulation Land-use (Plan) :Le Morne

5.3.3 Improvement Plan for Beach Use

Beach use issues consist of 1) Beach cleaning 2) Vehicle access into public beaches, 3) Lack of drainage (sewerage) systems, and 4) Removal of sand grass/creepers. These issues and improvement plans for them are shown as follows.

Table 5.3.3 Problems and Proposed Measures of Beach Use Management

	Specific problems	Proposed measures
Beach cleaning	●Beach cleaning is carried out every day in the public beach by the beach cleaning contractors under the supervision of the Beach Authority. ●On the other hand, lots of garbage, marine litter and seagrass / algae / coral (hereinafter referred to as driftage) ends up on the beach in front of some privately lease land. These may cause problems to sanitation and the landscape.  	●Since seagrass/algae/coral (hereinafter referred to as driftage) is buried in the sand on the foreshore by janitors in front of hotels in the south of Le Morne every morning, the beach is kept in good condition. Buried driftage has a positive impact on conserving ecosystems, especially on various organisms and sea animals because it contributes to the marine food chain. ●It is recommended that this activity should be applied to other beaches, especially beaches in front of the leased properties such as hotels, leisure homes, camp sites, etc. in order to keep the landscape pristine, keep the beach in continuously clean conditions and also promote healthy ecosystems. ●It is important to put forward a beach cleaning proposal to the lessees by using leaflets etc., including the good examples mentioned above through local government such as the Local Authority, the District Council, and the Village Council. In addition, it is recommended that the local authority has periodic inspections, at least once a month, of beach cleaning conditions on the beach. As part of the beach environment improvement, it is also necessary to advise the lessee to do the beach cleaning at areas where drift seaweed and garbage are remarkably deposited on the beach in order to keep a good beach environment.
	●Lots of garbage and driftage are deposited at some leased properties. It is assumed that this occurs in front of the leisure homes because the owners are not living there at all times. ●A lot of garbage and driftage are left on the beach at undeveloped areas nestled between hotels. It is a problem from the standpoints of landscape and usage.	●It is difficult to do the cleaning every day at the leased properties of the leisure home areas. In order to solve this problem, it is necessary to study establishing a new beach cleaning system or to modify the existing system to keep conditions clean for the whole area. It is recommended that a clause is added to the lease agreement to the effect that the lessee shall clean plastics and other solid wastes on the beach in front of leased land and the local authorities or the MHL shall periodically monitor and call attention to the lessee to stick to the clause.
	●Albion: A lot of garbage accumulates in the ditch in front of the beach. It might flow out to the sea after the it	● The beach in front of the AFRC is next to the public beach. A lot of people use this beach, especially on the weekends.

Specific problems	Proposed measures
rains.	Therefore, it is necessary to confirm the locus of responsibility of beach management and necessary actions to keep the beach clean.
● A lot of algae and seagrass drift down to the beach at and in most of the beaches in the east and northern coast every day. Sand clings to algae and seagrass. They are collected with sand and loaded onto the truck and carried to the disposal site. There is a possibility that this activity will impact the outflow of sand if it continues for a long period. At Flic en Flac, it was estimated that the amount of seaweed/sand/coral that are removed on a yearly basis nearly equals the requirement for beach replenishment which is roughly 400 m^3 per year. If this amount of seaweed/coral/sand is buried at scarps on the beach, the need for beach replenishment would not arise. ● On a daily basis leaves that fall from trees are collected and disposed offsite. ● Beaches are raked during daily cleaning to remove solid wastes and leaves. By doing so, grass cover and soil fertility is affected. As a result grass does not grow well leaving the sand dune bare. Sand under the effects of winds and daily cleaning erode away around casuarinas trees leaving the lateral roots exposed. These exposed roots represent a danger to beach users and their presence does not favor sand accumulation in the dune, leading to gradual erosion of the dune. 	● In order to reduce the decrease of sand due to disposal of drift weed, the following countermeasures are recommended: ● Collected driftage should be buried on the beach above the HWM. Firstly it should be dried in the sun for a few days, then buried in the sand at scarps or around trees located on the sand dune. In doing so, the nutrient load in the sand dune would increase thereby favouring growth of bushes and trees and grass. Drift seaweed has been buried in the sand on the foreshore by some janitors in front of the hotels in the south of Le Morne every morning. Depending on volume of drift seaweed, backfilled driftage has a positive impact on reduction of sand movement, conservation of ecosystems and reduction of management costs. ● There are cases that drift seaweed have been used as compost for cultivated land near the beach in Mediterranean and African countries for a long time. They are also used to improve the quality of vegetables and fruits in Japan. Drift seaweed contains a lot of phytohormone such as potassium and auxin, minerals, and so on. ● Collected leaves, if buried in the sand would improve the soil and contribute to humus formation. This humus would improve the moisture content of the soil and also the nutrient load, thereby promoting growth of plants on the sand dune. In places where grass is absent, appropriate species of grass should be reintroduced. Improvement of grass cover has several benefits including sand retention, absorption of rainwater, prevention of surface runoff and therefore prevention of formation of gulleys and scarps on the beach, amongst others benefits. ● When beach cleaning, care should be taken not to remove grass from the dune. Exposed roots, as much as practical, should be covered with sand and grassed.

	Specific problems	Proposed measures
Vehicle access into public beach	●Many cars are parked at backshore of public beach because vehicles can freely access coastal vegetation. This activity influences the environment by impacting coastal fauna and flora. There are other problems, for example, car exhaust, reduction of utilization space and beach-user accidents . ●Vehicles also cause soil compaction thereby preventing vegetation regeneration and rainwater percolation, and therefore contributing to erosion of the beach /dune.	● St. Felix's public beach in the south of Mauritius has parking areas behind the coastal forest and driving into beach and coastal forest is prohibited. It is recommended that parking space should be prepared for beaches throughout Mauritius in a step-by-step manner considering various impacts. ● In addition, it seems that installation of signs and information boards rather than barriers has an effect on motorcycles entering public beaches. It is recommended to set up a boundary by shrubs and flowering trees with landscaping in mind. It is also necessary to consider setup of a pedestrian deck and/or walkway while keeping in mind people who need a barrier-free environment, reduction of motor cycle entries, and conservation of beach plants.
Lack of drainage system	●Runoff caused by rainwater from the landside washes away sandy beaches locally. 	● It is necessary to prepare a drainage plan by conforming to the road rehabilitation and improvement plan behind the coastal zone, especially at areas where local scouring of sandy beaches occurs due to rain drainage. ● Soakaway drains shall be constructed in between parking areas/ roadside and public space to catch any surface runoff. The dune should be well vegetated to minimize effects of surface water runoff. Any hardened sand on the public space due to anthropogenic effects shall be loosened regularly through daily maintenance.
	●Garbage accumulates in ditches close to beaches. It might flow out to the sea after it rains.	● It is necessary periodically remove and collect garbage in drains located in public beaches by the Beach Authority and in the other areas by the district council.
	●At Grand Sable and most of the east coast, a lot of garbage, driftage and tires have accumulated on the beach, and they are giving off a strong and bad odor around the beach.	● The condition of beach after implementation of the physical project has been remarkably improved in terms of water quality, odor, garbage and so on. It is difficult to evaluate quantitatively whether improvement of the environment is due to purification effects by nourished material or self-motivated cleaning by residents. It is important to involve residents from the planning stage and enhance awareness of beach cleaning and

Specific problems		Proposed measures
		management. ● The coast shall be regularly cleaned by the District Council ● Sensitization campaigns to refrain from littering the environment should be held with villagers and the public at large.
Removal of sand grass/creepers	●Coastal sand grass and creepers were removed by leaseholders at individual discretion at some places in the sedimentation area at the north of Pte. d'Esny, Albion, Belle Mare and some other beaches . 	● Coastal sand grass maintains the coastal ecosystem and also controls erosion and blown sand by reduction of external forces such as waves and winds. In addition, the grass is great for controlling temperature rises of sandy beaches. As a result, the grass makes a contribution to providing comfortable recreational space. ● It is vital to make the importance of planting protection known to the lessees by using leaflets etc. in which various effects of sand grass are written as mentioned above through the local government such as the Local Authorities, the District Councils, and the Village Councils.

Source：JICA Expert Team

5.3.4 Improvement plan of Organization and Management System in terms of Beach Management

As mentioned above, the improvement plan of organization and management system to solve various issues for beach management and maintenance management, land use management and beach use management is proposed as follows. Shading is added to the items and texts of especially important beach management plans to maintain a suitable coastal line as follows. In order to maintain the beach for a long time, a suitable beach management system which accords the following three beach management items is proposed in Section 7.3 as a specific example.

- Beach management system for beach re-profiling (Section 7.3.6)
- Management system in terms of contract and land use at leased areas in the coastal zone (Section 7.3.7)
- Management system in terms of sand reuse (Section 7.3.9)

Table 5.3.4 Improvement Plan of Organization and Management System (proposed)

Items of management		Improvement plan of organization and management system (proposed)
Beach management and maintenance	Management of beach nourishment	● It is necessary for a qualified surveyor to survey to obtain accurate and formal data before and after beach nourishment. However, it is necessary to coordinate between MOESDDBM and MHL whether MOESDDBM trains qualified surveyors or qualified surveyors from MHL conduct the surveys. ● Periodic and continuous beach monitoring is very important. If the ICZM section continues to carry out beach profile surveys, maintaining quality and organization in the ICZM of MOESDDBM will be a concern due to the transfer or resignation of experienced persons. It is necessary to establish comprehensive organization in MOESDDBM to control beach monitoring, data management and analysis by GIS and database and budgetary steps for the organization are also needed. ● If sand at accumulated areas is moved to the eroded area through sand recycling and sand bypassing (system), etc., it is necessary to identify property boundaries at accumulated areas. It is important to share information in regard to existing and updated property boundaries between MOESDDBM and MHL at all times because the boundaries are managed by MHL and beach conservation is managed by MOESDDBM. Prompt and smooth beach nourishment and management can be done if information sharing between them is improved.
	● Management of formation of scarp ● Plantation on the beach	● In order to control expanding of scarp, it is important to quickly convey information about the existence or non-existence of scarp to MOESDDBM. It is necessary to improve communication systems from the Beach Authority, who is in charge of daily beach cleaning, to MOESDDBM, who is in charge of beach management, in order to speed up communication between them. As a result, MOESDDBM is able to carry out site reconnaissance surveys and beach profile surveys as early as possible. Therefore, suitable beach management can be done by understanding shoreline changes and the erosion rate. In addition, it is also recommended to enforce collaboration structures between MOESDDBM and MHL if damaged or wide eroded areas exist. ● The main causes of scarp forming are: 1) high waves such as cyclone-generated high waves, 2) exposed roots of trees due to an unbalanced sediment budget and 3) inadequate shape of beach nourishment. In terms of 1), it can be improved by cooperation between the Beach Authority and MOESDDBM as mentioned above. Regarding 2), as much as possible, it is important to select suitable species of beach plant and native species. The planting plan should be discussed among MOESDDBM, the Beach Authority and the Forestry Service/NPCS. In regard to 3), it is important that MOESDDBM confirms whether the planned foreshore slope is secured according to the completion inspection.

Land use Management	Existing coastal facilities	● It is necessary to evaluate and understand the effects and impact of existing coastal facilities in and around the beach. If impacts by existing facilities on the beach were found, it is necessary to consider demolition or reduction of the scale of existing facilities through discussion between lessees who owns them and related institutions. Demolition will be considered in renewal of the lease contract or renovation of facilities. But it is important to coordinate with the lessee to demolish facilities as early as possible if existing facilities have a remarkable impact on the beach. In terms of cost allocation for these cases, demolition with renewal of lease contract or renovation of facilities should be borne by the lessee if they will be demolished over time. For facilities which have a significant impact on the beach, it is necessary to study and discuss new cost allocation systems such as cost sharing between the owner and government. ● The vertical revetments cause enlargement of reflective waves, wave overtopping, scouring of nourished sand, and beach erosion in and around the beach. They are also an obstacle to landscaping and beach use. Demolition or modification of the revetments to sloping permeable type is recommended gradually as mentioned in the coastal conservation plan. On demolition or modification of the revetment, it is important to discuss, prepare the implementation plan and continue to monitor the shoreline change between not only government sides such as MOESDDBM, MHL, MoLG and the Beach Authority but also the lessees.
	Dredging at coastal area	● Dredging and sand recycling have been carried out at Le Morne, Ile aux Cerfs and Flic en Flac in priority coasts. There is a high possibility that the sand recycling will be carried out at Pte. d'Esny, Pte. aux Sables, Bel Ombre, T. d'Eau Douce, Bras d'Eau, Baie du Tombeau and so on as beach conservation measures in thefuture. ● It is necessary for MOESDDBM to confirm periodically the impact in and around the beach at Le Morne and Ile aux Cerfs because lessees have carried out the dredging voluntarily. ● It is important to verify the boundary of the property, preparation of implementation program, monitoring after sand extraction and site dumping in cooperation with MOESDDBM, MHL and MoLG at the site where the public beach intermixes with the leased area. ● It is also important to cooperate with MoF and MOI in terms of the monitoring of change of water quality and impact on coral after dredging and dumping sand.

	Existing facilities and structures within dynamic beach zone (including setback area)	● The monitoring system, including checking the presence of inadequate facilities on the beach, should be enforced in cooperation with MOESDDBM, MHL, MoLG, the Beach Authority and MoF accordingly. ● The monitoring for property boundary confirmation and the presence of inadequate facilities on the beach at accumulated areas should be carried out in cooperation with MOESDDBM, MHL and MoLG because the sand at accumulated areas may be used for sand recycling and sand bypassing in the future. ● Depending on the erosion speed, it is important to set up a 30 m setback line and clearance. It will be determined by MOESDDBM during evaluation of EIA in case of construction of hotel and residences at the eroded area.
	New construction within dynamic beach zone (including setback area)	● The presence of facilities in the setback area during EIA should be checked and well understood in cooperation with MOESDDBM and MHL. ● The position and specification of new buildings according to the plan should be checked together with MOESDDBM, MHL, MoLG, the Beach Authority and MoF (if necessary) before and after construction. In addition, the presence of inadequate facilities should also be checked after construction by obtaining photographic evidence right after the construction.
	Management system in terms of contract and land use at leased land area	● The review of boundaries at the leased land area is carried out by MHL as the permit approval agency for contract renewal. ● The leased land at sedimentation area should not be expanded to the seas side more than the original contract line in consideration of maintenance of sandy beach in the future. ● In case of leased land at eroded areas, lost land due to erosion should be not be counted in the renewal contract. ● The lease contract period is for 60 years as mentioned above. It should be reviewed every 10 years, or at least every 20 years considering mid- and long-term coastal changes . ● It is necessary to secure public domain considering clarification of boundary between public, private and beach use. ● The specific management system as mentioned above is described in Section 7.3.7 in detail.

Beach use management	Beach cleaning	● The inspection of beach cleaning at the lease area where hotels and houses exist should be carried out together with the Beach Authority, MoLG and MOESDDBM accordingly. If bad conditions are found on the beach at the lease area, they should urge the lessee to improve the bad conditions. Moreover, it is necessary to consider including responsibility of beach cleaning in the lease agreement for the lessee by MHL. ● The most of the public beaches are kept in a clean state but insufficiency of beach cleaning was found near boundaries between public and private areas. An inspection of beach cleaning at this area should be carried out together with the Beach Authority and MOESDDBM about once every three months. And it is necessary to clarify that it is the responsibility of the lessee to do the cleaning at this area and discuss how to improve this condition between the lessee and the government under joint inspection.
	Vehicle access on public beach	● A lot of cars and motorcycles enter public beaches, especially on the weekends. A patrol for driving into public beaches should be carried out together with the Beach Authority and MOESDDBM about once every three months in order to discuss the improvement plan. The joint patrol should continue even if countermeasures were worked out.
	Lack of drainage system	● It is necessary to discuss and study countermeasures against insufficiency of drainage and sewerage facilities together not only with MOESDDBM but also the road administrator and the sewerage administrator if scoured places are found due to inadequacy of drainage facilities or inflow of sewage water..
	Removal of sand grass/creepers	● The inspection for coastal sand grass should also be carried out together with MOESDDBM, MHL and MoLG once a year at the time of inspection for existing facilities and structures within the setback area as mentioned above.

Source : JICA Expert Team

Based on organization and management system to each management item as mentioned above, responsibilities among related institutions and frequency of beach management are summarized as follows. The upper and lower column in this table shows existing and proposed responsibility respectively.

Table 5.3.5 Responsibilities among Related Institutions and Frequency of Beach Management (Proposed)

Management items		Frequency	Related institutions						
			MOESDDBM	MHL	MoLG	The Beach Authority	Forestry Service	MoF	MOI
Beach Management and maintenance	Maintenance and monitoring for beach nourishment	Accordingly	◎						
			◎	○		○			
	Formation of scarp	Accordingly	◎		◎	◎			
			◎		◎	○	△		
	Plantation on the beach	Accordingly					◎		
			○			○	◎		

Management items		Frequency	Related institutions						
			MOESD DBM	MHL	MoLG	The Beach Authority	Forestry Service	MoF	MOI
Land use management	Existing coastal facilities	Accordingly	◎	◎	◎(DC)				
			◎	◎	◎	○			
	Dreading in coastal area	Accordingly	◎	◎				◎	
			◎	◎	○			◎	△
	Existing facilities and structures within dynamic beach zone	Accordingly	—	—	—	—	—	—	—
			◎	◎	○	◎		◎	
	New construction of structure within dynamic beach zone	Before and after construction	◎	◎	◎	◎		◎	
			◎	◎	◎	◎		◎	
Beach use management	Beach cleaning	Accordingly			◎	◎			
			○	◎	◎	◎			
	Vehicle access on public beach	Accordingly			◎	◎			
			○		◎	◎			
	Lack of drainage system	Accordingly	—	—	—	◎	—	—	—
			◎			◎			
	Removal of sand grass / creepers	Accordingly			◎	◎			
			◎	◎	◎	◎	○		

Remarks : ◎Responsible, ○Sub-responsible, △Cooperator, －Unproven
Upper : Existing responsibility, Lower : Proposed responsibility
Source : JICA Expert Team

5.3.5 Proposal for Improvement of Existing Regulations based on Beach Management Issues

Existing regulations for beach management as mentioned in Chapter 2 are listed as follows.

- Definition of Coastal Zone :Environmental Protection Act, 2002 (EPA2002)
- Ownership in Coastal Zone: State Lands Act, 1982
- Definition of public beaches: Beach Authority Act, 2004
- Regulation for Landward Buildings and Structures from H.W.M: Design Sheet, Residential Coastal Development, 2004
- Regulation for Seaward Buildings and Structures from H.W.M: (Planning Policy Guidelines) Planning and Development Act, 2004

- Environmental Impact Assessment: EIA, EPA, 2002
- Conservation of Biodiversity: Forest and Reserves Act, 1983, Wild life Act, 1993, Fisheries and Marine Resources Act, 2007

The improvement plan for existing regulations to be applied based on beach management issues as mentioned above is recommended as shown in Table 5.3.6. The upper part of the column in this table shows the regulation(s) to be applied against each issue and the lower part of the column shows improvement plan for regulations.

Table 5.3.6 Improvement Plan for Regulations against Beach Management Issues (Proposed)

Management item		Existing regulations to be applied Regulations to be improved (proposed)
Beach management and maintenance	Management for beach nourishment	No regulations to be applied for beach nourishment. As per EPA beach re-profiling and modification of shoreline are scheduled activities requiring EIA Note: To differentiate between extensive works having impact on environment and minor maintenance work.
		Beach nourishment was conducted in a public beach in Mauritius up until now. If it is conducted on leased land area, it is necessary to establish new rules and regulations in terms of organization and cost allocation and so on in addition to EIA for evaluation of impact on the environment due to the construction. In order to implement it smoothly, it is best that it be implemented by the organization with the cooperation of the public and private sectors.
	Management for scarp	No regulations to be applied for management of scarps
		It is necessary to enforce coordination among related institutions with a focus on MOESDDBM, the Beach Authority and MoLG as mentioned above.
Land use management	Existing coastal facilities	Fisheries and Marine Resources Act, 2007, Planning and Development Act, Beach Authority Act, EPA, 2002
		The existing vertical revetments were constructed at the discretion of the lessees before establishment of the regulations mentioned above. It is important to regulate structures without permits based on the above regulations.
	Dredging in coastal area	EIA (EPA2002), Fisheries and Marine Resources Act, 2007, Removal of Sand Act, 1982
		It is necessary to evaluate the impact in and around the site qualitatively and quantitatively after dredging work. Already require by EIA as per EPA.
	Existing facilities and structures within setback area	Design Sheet, Residential Coastal Development, 2004, Planning and Development Act, 2004
	New construction of structure within setback area	There are facilities constructed around 2004 that do not abide by the setback rules of 15 and 30 m at some beaches, as mentioned above. It is necessary to instruct the facility owners to demolish or relocate the facilities that do not abide by the setback regulation. It would be optimal if clarification of the boundary, demolition of illegal and inadequate facilities, replacement permits and so on were added in the Design Sheet.

Beach use management	Insufficient beach cleaning	Beach Authority Act, 2004, Local Government Act The cleaning has been conducted well at the public beaches but insufficient beach cleaning is found at leased land and around the boundary between leased land and the public beach. It is necessary to draw up a set of new rules and enlighten others through information activities in these areas.
	Vehicle access into public beach	Beach Authority Act, 2004 It is necessary to consider enforcement of surveillance systems, installation of signs and information boards as well as an awareness campaign as mentioned above.
	Lack of drainage systems	Beach Authority Act, 2004 Necessary budget allocation to be provided to BA
	Removal of sand grass/creepers	No regulations at present It is necessary to conduct a PR awareness program to set up new rules and to include Policy Planning Guidelines (PPG).

Source: JICA Expert Team

5.4 Beach Management Plan from the Point of View of Integrated Sand Management

This section is based on coastal conservation and is intended for beach nourishment study. This section focuses on prior maintenance including sand recycling and sand bypassing. The study items are shown below. In addition, beach management plans that should be considered on each target beach individually are described in Volume 2.

- [Section 5.4.1] Summary of coastal conservation plan and volume of beach nourishment at priority coasts
- [Section 5.4.2] Summary of sediment budget and basic concept of beach management at propriety coasts for priority coasts
- [Section 5.4.3] Beach management issues
- [Section 5.4.4] Improvement plan of beach management in coastal area
- [Section 5.4.5] Potential for removal of sand in and out of lagoon and future issues

As mentioned above, future issues and actions regarding beach re-profiling that are important for beach management and plan/land use at leased lands in coastal areas are recommended in Section 7.3.

5.4.1 Summary of Coastal Conservation Plan and Volume of Beach Nourishment at Priority coasts

It is necessary to understand what kind of beach management is required in order to keep the beach in good condition in the medium and long-terms after project implementation at priority coasts. This information will be required in order to set up planning of management and maintenance, budget allocation and implementation organization in the future. The beach

conservation plan for priority coasts is summarized as follows:

Table 5.4.1 Summary of Beach Conservation Plan and Beach Nourishment Volume at Priority Coasts

No.	Priority coasts	Summary of beach conservation plan	Volume of beach nourishment
1	Baie du Tombeau	● Renovation of revetment, etc. ● Reconstruction of pedestrian bridge	—
2	Pte. aux Cannoniers	● Erosion area on the north side : Beach nourishment + artificial rocky shore (if necessary), demolition of existing revetments in beach nourishment area	5,000m^3 (volume of sand lost for 40 years)
		● Erosion area on the east side : Beach nourishment + groyne, improvement of revetment in the beach nourishment area	10,000m^3 (volume of sand lost for 40 years)
3	Mon Choisy	● Beach nourishment (suitable grain size) + beach re-profiling	Initial nourishment : 5,000m^3 After second nourishment : 1,000m^3/every 2 years
4	Bras d'Eau	[Short term measure] ● Re-profiling / sand recycling ● Transplantation of mangrove and marine plants [Mid- to long-term measures] ● Relocation of public toilet	Approximately 200 m^3 /year (Dreading and sand recycling)
5	T. d'Eau Douce	● Setback ● Renovation of existing vertical revetment to gentle slope revetment	—
6	Ile aux Cerfs	● Dredging of sediment sand + Filling sand into the erosion area (Sand recycling)	Approximately 2,000m^3/year (Dredging and sand recycling)
7	Pte. d 'Esny （Blue Bay)	● Beach nourishment (including Sand recycling) ● Re-arrangement of coastal protection facilities such as groynes, etc. ● Setback ● Combination of above items	Approximately 10,000m^3 (sand recycling in the beach or procurement of sand from outside)
8	Bel Ombre	● Setback	—
9	Le Morne	● Sand bypassing ● Renovation of training jetty ● Coral transplantation	Approximately 800 m^3 / year: sand bypassing

10	Flic en Flac	● Sand recycling ● Coral transplantation	Approximately 2,000m^3/year (Dredging and sand recycling)
11	Albion	● Setback ● Transplantation of coral and marine plants	-
12	Pte. aux Sables	● Sand recycling from sedimentation area on the east side to erosion area at both sides of new revetment	Initial beach nourishment: 4700 m^3 Periodic nourishment: 2000 m^3/2 years
13	Grand Sable (Physical Pilot Project)	[Short-term measures] ● Flexible gravel nourishment [Long term measure] ● Regrading of road	Gravel: 7,700 m^3 Sand: 940 m^3
14	Albion (Cliff)	● Setback	—

Source: JICA Expert Team

5.4.2 Summary of Sediment Budget and Basic Concept of Beach Management at Priority coasts

The summary of sediment budget is shown as follows:

- The overall and annual sediment budget for the past 45 years (1967-2012) and for the past 15 years (1997-2012) at priority coasts are shown in Table 5.4.2. According to the sediment budget for 45 years, overall and annual sediment budget were approximately + 390,000 m^3 and + 8,700 m^3/year respectively. The eroded beaches are shown at three beaches, namely, Mon Choisy, Pte. Aux Cannoniers and Albion. The most serious eroded beach is Mon Choisy and its overall erosion rate is -22,400 m^3 and annual average erosion rate is -498m^3. The erosion rate at Pte. aux Cannoniers and Albion is around 200m^3/year.

- According to the sediment budget for 15 years (1997-2012), the erosion tendency at Mon Choisy and Pte. aux Cannoniers is the same as the tendency of the past 45 years. In addition, the erosion at the north and east side of Pte. aux Cannoniers is remarkable. The erosion rate of both sides is approximately 1,200 m^3/year. In the long run the sediment budget shows a tendency of accumulation at Le Morne and Bras d' Eau over the past 45 years, but in the short run, namely the last 15 years, it shows an erosion tendency. On the other hand, the sediment budget at Albion shows an erosion tendency in the long run but in the short run it shows an accumulation tendency. Remarkable accumulation was shown at the river mouth on the south side of this beach. It is assumed that the accumulation is due to sand flushing from inland. All sub cells except the accumulation area shows erosion tendencies.

- The basic concept of beach management for the nine beaches, which show a long-term accumulation tendency, is to keep a balanced sediment budget by periodic maintenance such as sand recycling from accumulation areas to erosion areas. The basic concept of beach management at Le Morne and Bras d Eau, which show short term erosion tendencies, is also basically sand bypassing and/or sand recycling as well

as other beaches. But it is necessary to consider procuring sand from outside of the beach if the sediment budget shows a decreasing trend in the future.

- At Mon Choisy and Pte. aux Cannoniers, which show both short-term and long-term decreasing trends of the sediment budget,, it is necessary to continuously install sand for beach maintenance in order to keep the beaches in good shape. The necessary sand for beach management should be procured from outside of the beach. The procurement method is showed in the next section.

- The volume of accumulated sand at Ile aux Cerfs is approximately 170,000 m^3 over the past 45 years and 3,800m^3/year and its volume is the largest among priority coasts. Dredging work was carried out between islands in order to keep the channel open and the hotel who manages the channel has been anxious about disposal of dredged sand. It is recommended that the sand be reused as beach nourishment material for other beaches.

Table 5.4.2 Sediment Budget in the Long Run (In the Past 45 Years) and in the Short Run (In the Last 15 Years)

Target beaches	1967-2012 in the last 45 years		1997-2012 in the last 15 years	
	Sedment budget (m^3)	Annual sediment budget (m^3/Year)	Sedment budget (m^3)	Annual sediment budget (m^3/Year)
Baie du Tombeau	17,675	393	15,700	1,047
Pte. aux Cannoniers(North)	-2,425	-54	-14,025	-935
Pte. aux Cannoniers(East)	-6,925	-154	-4,975	-332
Mon Choisy	-22,400	-498	-7,650	-510
Bras d' Eau	9,283	206	-5,734	-382
T. d'Eau Douce	17,750	394	11,675	778
Ile aux Cerfs	171,250	3,806	26,850	1,790
Pointe d'Esny	17,575	391	16,625	1,108
Bel Ombre	63,350	1,408	28,225	1,882
Le Morne	55,950	1,243	-8,075	-538
Flic en Flac	23,775	528	40,725	2,715
Albion	-7,748	-172	3,447	230
Pointe aux Sables	53,750	1,194	37,400	2,493
Amount	390,861	8,686	143,488	9,566

Source: JICA Expert Team

5.4.3 Beach Management Issues

Very important points for beach management after implementation of coastal conservation measures at priority coasts are continuous filling sand and adequate reuse of sand at the same coastal area in order to maintain sandy beaches in the long term.

Two cases are pointed out as beach management by sand recycling and sand bypassing at priority coasts. One case is sand recycling that extracted sand at the sedimentation area on the north side of Flic en Flac and was transported to an up-drift public beach experiencing erosion by dump truck for nourishment in June 2014. The second case is sand bypassing at Ile aux Cerfs. Accumulated sand in the channel was transported to down drift on the north side. On the other hand, according to a hearing survey from Hotel Le Paradis at Le Morne, they have dredged accumulated sand in the channel and stocked it behind the beach, and they also applied to the government for beach filling at the erosion area of down drift by using

dredging sand as a sand bypassing measure. However, the application has failed and they still are unable to carry out sand bypassing.

It is conceivable that the following things enabled sand recycling and sand bypassing at these beaches:

- In the case of Flic en Flac, the government, MOESDDBM was able to easily carry out sand recycling from the planning/construction stages to monitoring after implementation because both the sedimentation and erosion area were located on public beaches.

- In the case of Ile aux Cerfs, the hotel is able to carry out beach maintenance through sand recycling by their own budget because both the sedimentation area and erosion area are leased by the same owner. The situation of Le Morne is also the same as that of Ile aux Cerfs, so the hotel can carry out sand bypassing from up-stream to down-stream if the application is approved by the government.

As mentioned above, it is possible to carry out sand recycling and bypassing if both the erosion area and sedimentation area are managed by the public or the same lessee. However, sand recycling and bypassing have not been carried out before where public areas and leased areas are mixed in the erosion area and sedimentation area. Also sand recycling and bypassing have not been carried out if leaseholders are mixed in the leased area. These issues are summarized below. Some issues for the above mentioned cases that have a past record of sand recycling and bypassing are also described in the Table.

Table 5.4.3 Summary of Principal Issues for Beach Management and its Appropriate Beach

Case	Condition of beach		Principal issues	Appropriate beach
	Sedimentation	Erosion		
Case－1	Public area	Leased area	● The cost for EIA and construction in terms of sand recycling/bypassing is born by the lessee. ● It is difficult to gain concensus on the sharing of expenses and which contractor to select if there is a number of lessees in the erosion area. ● It is necessary to establish an organization to facilitate cooperation between the public and private sectors, as well as the citizens because continuous beach management is required.	● T. d'Eau Douce (South) ● Bel Ombre *Note : There is some possibility of sand bypassing ans recycling in the future.*

Case－2	Leased area	Public area	● It is necessary for the government to explain to the lessee about the necessity of sand extraction at sedimentation areas and the impact after extraction based on technical grounds . ● Clarification of boundaries between the leased area and sedimentation area is required. ● Understanding and agreement by lessees as mentioned above is required. ● It is necessary to establish organization under cooperation between the public and private sectors, as well as the citizens because continuous beach management is required. ● Securing road access is required. ● Discussion and acceptance of the construction plan and period is required between government and lessees	● Pte. aux Sables *Note : Proposed in CCP in Volume 2* ● T. d'Eau Douce (North) *Note : There is some possibility of sand bypassing ans recycling in the future.*
Case－3	Leased area	Leased area	● It is required to explain the necessity of sand extraction and filling both at the sedimentation area and at the erosion area and the impact after implementation based on technical justification to lessees. ● Clarification of boundaries between the leased area and the sedimentation area is required. ● Understanding and agreement to cooperate between lessees of both areas is required. ● Coordination of cost burden between the lessees in the area and selection of a contractor is required. ● It is necessary to establish an organization between lessees because continuous beach management is required. ● In order to carry out maintenance smoothly in the future, an organization which conducts sand extraction for sand nourishment is required. ● Securing road access is required. ● Discussion and acceptance about the construction plan and period is required between lessees . ● Various coordination and support of the government to lessees is required.	● Pte. d'Esny *Note : Proposed in CCP in Volume 2* ● Bel Ombre ● Baie du Tombeau *Note : There is some possibility of sand bypassing ans recycling in the future.*
	Public area	Public area	● No particular issues exist. However, continuous monitoring and maintenance are required.	● Flic en Flac ● Bras d'Eau *Note : Proposed in CCP in Volume 2*
	Same lessee		● There is no issue regarding procurement of sand. ● Periodic monitoring and maintenance is required. ● Periodic control and advice are required by third parties like MOESDDBM.	● Ile aux Cerfs ● Le Morne *Note : Proposed in CCP in Volume 2*

Source: JICA Expert Team

The various issues of each case were pointed out as mentioned above. The improvement

concept for these issues is described in the next section "5.4.4 Improvement plan of beach management in coastal area".

5.4.4 Improvement Plan of Beach Management in Coastal Areas

Regarding the sedimentation and erosion areas, in cases where sand recycling and bypassing are carried out within the beach, the issues will be different depending on whether the sedimentation areas are public or leased, as mentioned above. The policy for improvement measures on each issue of three cases as mentioned above is described as follows.

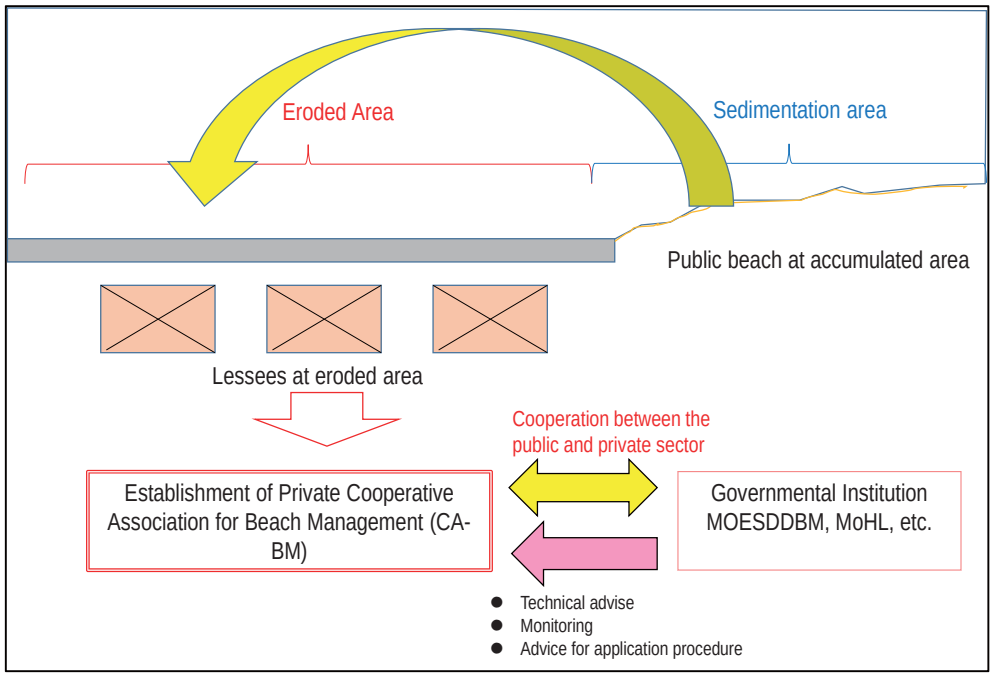
a. Case-1: Sedimentation area (Public area), Erosion area (Leased area)

The policy for improvement measures on the main issues of sand extraction and beach nourishment where the sedimentation area is a public area and the erosion area is a leased area is shown below. In addition, the implementation system (Plan) and cost allocation and flow of the construction (Plan) are proposed in Figure 5.4.1 and Figure 5.4.2 respectively.

Table 5.4.4 Principle Issues and Policy for Improvement Measures for Case-1

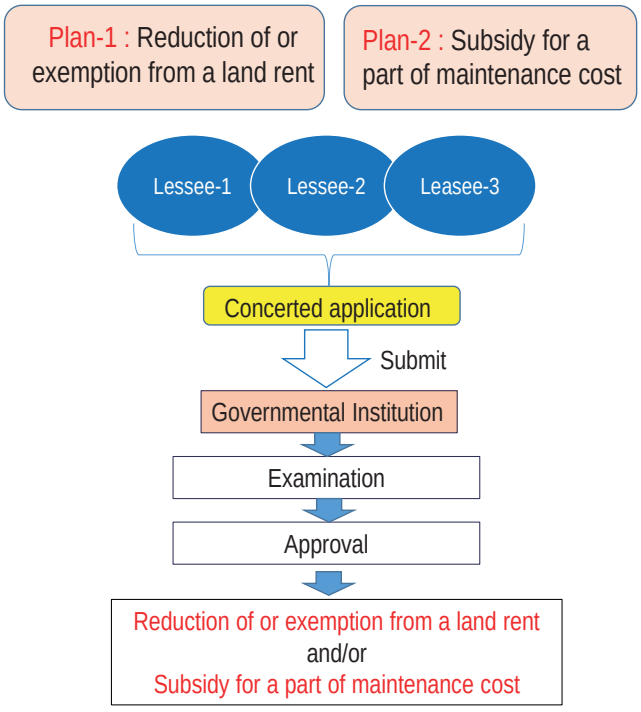
Principle issues	Policy for improvement measures
The cost for EIA and construction in terms of sand recycling/bypassing is born by lessee	● A number of lessees often exist in the erosion area. Therefore,it is recommended to establish a committee or association which can discuss management methods, cost allocation, procurement of a contractor, etc. (refer to Figure 5.4.1)
It is difficult to lead to discussion and agreement about allotment of expense and contractor between lessees if a number of lessees exist in erosion area.	● It is necessary to coordinate the public agency with sand extraction because the sedimentation area is a public area. It is also important to advise on filling volume, method, frequency of monitoring and maintenance from the point of view of technical grounds. Therefore, it is necessary to establish a beach management structure (framework) to facilitate cooperation between the public and private (lessees, hotels, etc.) stakeholders because discussion and coordination between them are required. (refer to Figure 5.4.1)
It is necessary to establish organization under cooperation between public and private because continuous beach management is required.	● The financial burden for initial sand extraction, filling, continuous monitoring and maintenance will become heavy for the lessees. In order to back up self-motivating beach maintenance by the private sector, it is recommended to consider reduction of or exemption from land rent as shown in plan-1. Another option is to offer a subsidy for a part of the maintenance costs from government to lessees in this area as shown in plan-2. In this regard, joint application by a number of lessees is recommended.(refer to Figure 5.4.2).

Source: JICA Expert Team



Source: JICA Expert Team

Figure 5.4.1 Implementation System under Cooperation between the Public and Private Sectors (Proposed): Case-1



Source: JICA Expert Team

Figure 5.4.2 Support System for Beach Maintenance (Proposed)

b. Case-2: Sedimentation area (Leased area), Erosion area (Public area)

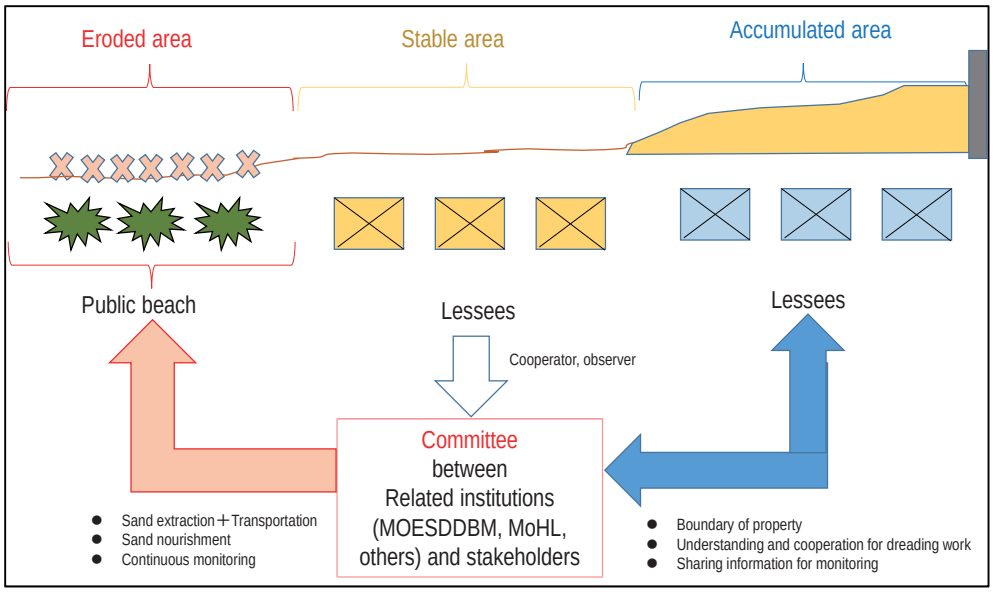
The policy for improvement measures on main issues of sand extraction and beach nourishment where the sedimentation area is the leased area and the erosion area is a public area is shown is shown below. In addition, an implementation system under cooperation

between the public and private sectors (Plan) is proposed in Figure 5.4.3. In these cases, the maintenance cost from sand extraction to beach nourishment will be covered by the public side.

Table 5.4.5 Principle Issues and Policy for Improvement Measures for Case-2

Principle issues	Policy for improvement measures
It is necessary to explain to the lessees about the necessity of sand extraction and filling both at the sedimentation area and at the erosion area and the impact after implementation based on technical grounds.	● The related agencies (e.g.MOESDDBM) offer information to lessees regarding the sediment transportation mechanism, impact to hinterland after sand extraction, environmental impact, required maintenance in the future and so on. It is necessary to get an understanding and consensus from the lessees. Explanation and consensus building are required in the planning phase, before and after construction and during periodic monitoring and maintenance. (Refer to Figure 5.4.3)
Clarification of boundaries between the leased area and the sedimentation area is required.	● It is necessary to verify the boundaries between the public and private through joint survey between them based on lease contracst. ● It is also necessary to install boundary stakes in order to smoothly proceed with maintenance in the future.
Understanding and agreement by lessees as mentioned above is required.	● Same as mentioned above.
It is necessary to explain to the lessees about the necessity of sand extraction and filling both at the sedimentation area and the erosion area and the impact after implementation based on technical grounds.	● Establishment of a committee in order to enhance cooperation between the public and private such as related agencies (MOESDDBM, etc.) and lessees at the sedimentation area ● Sharing of information regarding construction methods for maintenance, construction schedule/period, and result of monitoring ● Continuous and smooth monitoring and maintenance through periodic meetings (Refer to Figure 5.4.3)
Securing road access is required.	
Discussion and acceptance of the construction plan and period between government and lessees is required.	

Source: JICA Expert Team



Source: JICA Expert Team

Figure 5.4.3 Implementation System under the Cooperation between the Public and Private Sectors (Proposed): Case-2

c. Case-3: Sedimentation area (Leased area), Erosion area (Leased area)

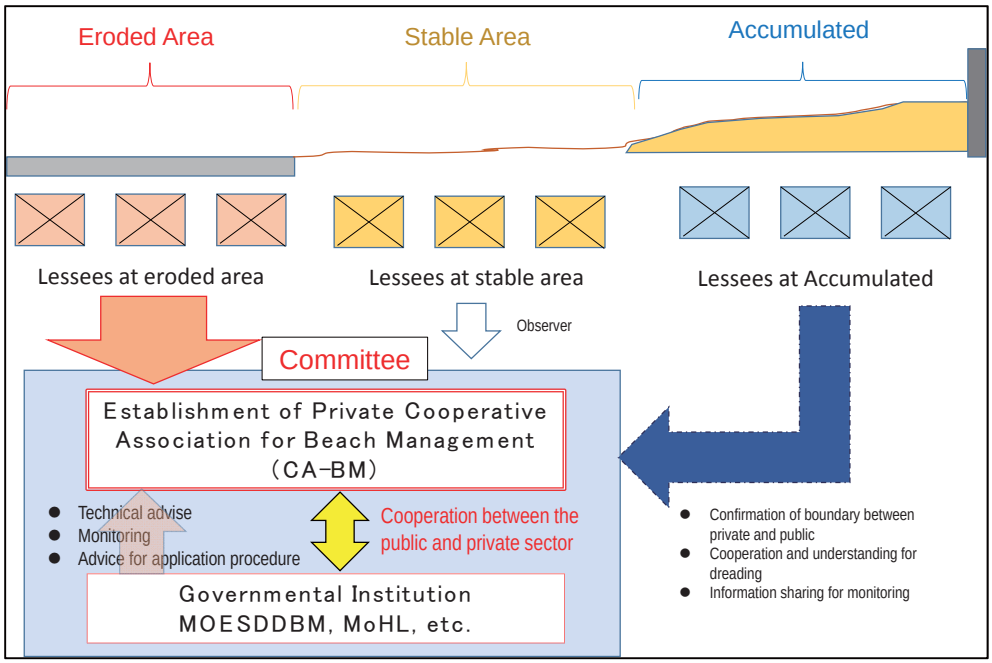
The policy for improvement measures on main issues of sand extraction and beach nourishment where the sedimentation area and erosion area exist together on leased areas are shown below. In addition, implementation system under cooperation between the public and private sectors (Plan) is proposed in Figure 5.4.4. In these cases, the maintenance cost from sand extraction to beach nourishment in addition to a support system will be covered by the lessees. Figure 5.4.2 is proposed for this case.

Table 5.4.6 Principle Issues and Policy for Improvement Measures for Case-3

Principle issues	Policy for improvement measures
It is necessary to explain to lessees the necessity of sand extraction and filling both at the sedimentation area and the erosion area and the impact after implementation based on technical grounds.	● It is necessary for related agencies (MOESDDBM, etc.) to offer technical support by providing information about littoral drift mechanisms, impact to the hinterland due to sand extraction, environmental impact, the maintenance plan in the future and so on in order to obtain the understanding of lessees at sedimentation and erosion areas. ● It is important to gain a better understanding of the effects of maintenance through information from related agencies (MOESDDBM, etc.) to lessees regarding monitoring data after beach nourishment in order to smoothly proceed with maintenance. (Refer to Figure 5.4.4)
Clarification of boundaries between the leased area and the sedimentation area is required.	● It is necessary to verify the boundaries between the public and private through joint survey between them based on lease contracts. ● It is also necessary to install boundary stakes in order to smoothly go forward with maintenance in the future. (Refer to Figure 5.4.4)

Understanding and agreement to cooperate between lessees of both areas is required.	● A number of lessees often exist in erosion areas. It is recommended to establish a committee or association to facilitate management methods, cost allocation, procurement of a contractor, etc. at the erosion area.
Coordination of cost burden among lessees and selection of a contractor by lessees in the area is required	● Lessees of sedimentation areas attend a committee or association meeting as an observer in order to exchange information about sand extraction and transportation, shoreline changes after the extraction, etc. (Refer to Figure 5.4.4)
It is necessary to work to gain concensus amongst lessees because continuous beach management is required.	● As mentioned above, the cost burden of initial sand extraction and filling and continuous monitoring and maintenance will become heavy for lessees. In order to support self-motivating beach maintenance by the private sector, it is recommended to consider reduction of or exemption from land rent as plan-1 shows and/or offer a subsidy for part of the maintenance costs as plan-2 shows from the government to lessees in this area. In this regard, joint application by a number of lessees is recommended (e.g. group subsidy system). (Refer to Figrue 5.4.2)
In order to carry out maintenance smoothly in the future, organization from sand extraction to filling is required.	● It is necessary for related agencies to support lessees about selection of a contractor, application for subsidies and so on. (Refer to Figure 5.4.4)
Securing road access is required.	● Establishment of committee in order to enhance cooperation between the public and private such as related agencies (MOESDDBM, etc.) and lessees at the sedimentation area.
Discussion and acceptance of construction plan and period between lessees is required.	● Sharing information regarding construction methods for maintenance, construction schedule/period, and result of monitoring ● Continuous and smooth monitoring and maintenance through periodic meetings (Refer to Figure 5.4.4)
Various coordination and support from the government to lessees is required..	

Source: JICA Expert Team



Source: JICA Expert Team

Figure 5.4.4 Implementation System under the Cooperation between the Public and Private Sectors (Proposed): Case-3

5.4.5 Potential for Removal of Sand in and out of Lagoon and Future Issues

It is necessary to obtain sand from outside of the beach in order to maintain a sandy beach, if implementation of sand recycling and bypassing is difficult within the beach area. In this case, procurement of sand from outside is limited to two sand pits (St. Felix and Macconde) in south Mauritius. However, at this point, it hasn't been confirmed if those sand pits have sufficient volume for the maintenance of sand nourishment. Therefore, it is also necessary to consider potentially procuring sand from not only outside the lagoon but also in the lagoon in order to maintain a sandy beach from a mid- to long-term viewpoint. But a ban on extraction of sand in the lagoon was placed by the government in 2001. The issues in the future and necessary actions are pointed out after due consideration of potential sand procurement from in and out of the lagoon. The following five cases were reviewed:

- Case-A: Potential sand extraction from island under formation in the lagoon (e.g. Baie du Tombeau)
- Case-B: Potential sand extraction from the sedimentation area in the lagoon and utilization as material for beach nourishment (e.g. Pointe d'Esny)
- Case-C: Potential use of dredged sand as material for beach nourishment for other beaches (e.g. Ile aux Cerfs)
- Case-D: Potential use of surplus sand on the lagoon which does not contribute to the sand supply for the beach (e.g. Ile aux Phares: opposite Bambous Virieux)
- Case-E: Potential use of sand which has been deposited in a deep area such as a reef gap (e.g. sedimentation sand around lagoon)

a. Case-A : Potential of sand extraction from island under formation in the lagoon and issues (e.g. Baie du Tombeau)

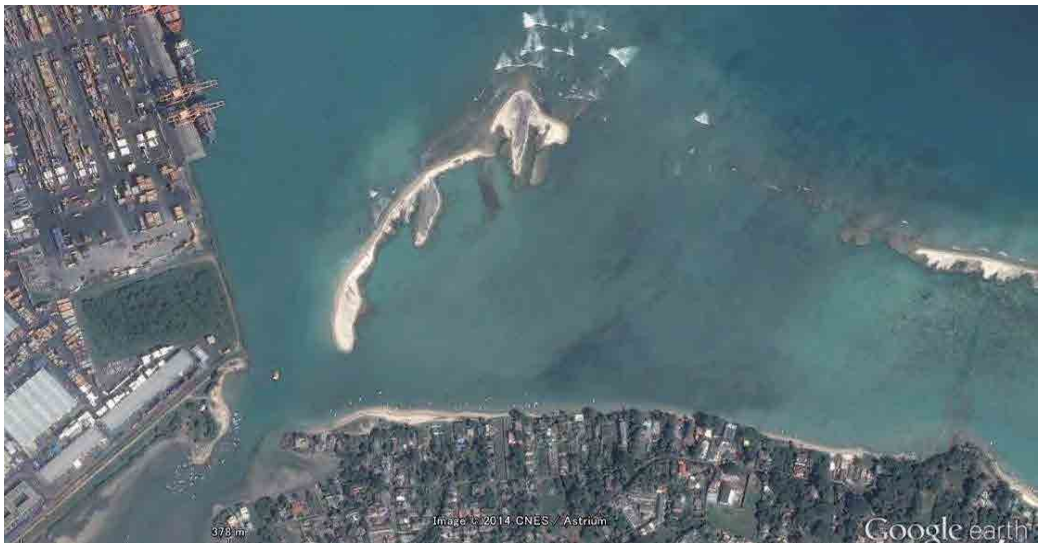
At Baie du Tombeau, a sandy island was formed due to accumulation of sand in the lagoon. It has still been growing gradually. This island is located in the lagoon at the southernmost part of this beach. The growth of this island and shoreline change in and around the beach are shown in Figure 5.4.5. This area of the island has developed about 2.5 times in size as compared with 2003 and 2014, from approx. 9,800 m^2 to approx. 25,000 m^2. This was calculated based on Google Earth in August 2003 and May 2014. It is assumed that sand had accumulated approx. 15,000 m^3 for the past 10 years if the thickness of sand on the island is about 1 m.

At down drift of the south part of the beach, the shoreline has been progressing in proportion to island development. It is thought that the cuspate shoreline (foreland) has formed offshore because development of the island has enhanced the effects of tombolo. On the other hand, According to satellite photos from 2014, it was confirmed that the foreshore north of the sedimentation area that had existed in 2003 has nearly disappeared. Therefore, the shoreline behind the island has been quickly advancing due to the rapid development of the island, and beach erosion has expanded due to sand movement from up-drift to down-drift.

At the moment, it is impossible to extract sand because sand extraction on the lagoon was banned in 2001. However, it is thought that the coastal condition behind the island can be stabilized if the size or shape of the island is adjusted by dredging because it is presumed that development of the island may influence the beach behind the island. The dredging sand can be used as beach nourishment material as well as maintenance for the eroded parts of this beach and other beaches that have not kept balanced sediment budget as mentioned above. It is also thought that comprehensive and flexible beach management would be favorable for Mauritius.

The issues are pointed out as follows;

- Study of impact on surrounding beaches due to sand extraction and necessity of EIA
- Peripheral people’s understanding and approval in terms of sand extraction from the technical point of view
- Application procedure special exception against ban of sand extraction on the lagoon
- Establishment of implementation system and cost burden from sand extraction to filling



Transition(Growing transition?) of small island at Area-1

Significant development of shoreline at Area-2

Siginificant retreat of shoreline and disaperelance of foreshore at Area-3

Source: JICA Expert Team

Figure 5.4.5 Transition of Sedimentation in Lagoon and Secular Change of Erosion and Sedimentation Area at Baie du Tombeau

b. Case-B : Potential of sand extraction from sedimentation area in the lagoon and utilization as material for beach nourishment and issues (e.g. Pt. d'Esny)

In the past 40 years, approx. 45,000 m^3 of sand has accumulated at area that ranges from groyne of north end to south (650 m in length) at Pt. d'Esny. The accumulation of sand has been continuing at this area, especially around the north end of groyne (G4) . The sand has overflowed the tip of G4, then the sand has accumulated on the lagoon on the north side of the groyne. According to the calculation results of the area based on satellite photos from Google Earth, the accumulated area on the lagoon has increased by about 2.5 times in size, from 7,000 m^2 in 2006 to 18,000 m^2 in 2014. Although site reconnaissance survey by boat was conducted in October 2014, the expose condition at the accumulated area could not be confirmed due to high water from the spring tide. It is assumed that the thickness of sand is about 2 m because the water depth is about 70 cm and 3 m, in and out of the accumulated area respectively. According to residential information, the accumulated sand has posed a problem for boat navigation due to significant development (or increase) of the accumulated area. In addition, residents had a strong desire for dredging in this area and also requested the sand be reused for beach conservation measures at the erosion area.

It is impossible to take sand from the lagoon because extraction of sand was banned by cabinet meeting in 2001 (CAB(2001) 12th Meeting-No.574, Sand Extraction-Cabinet Memorandum) as mentioned above. It is thought that the sand has overflowed the tip of groyne (G4) because of littoral drift from south to north. Also, sand has accumulated on the lagoon. Considering that sand moved from south (down-drift) and accumulated on the lagoon, to fill the accumulated sand to the erosion area of the south side becomes a part of the sand recycling system. It is necessary to modify regulations decided by cabinet meeting if sand extraction is going to be carried out on the lagoon. It is also necessary to review the legal system and/or establish new regulations through sufficient discussion among institutions concerned.

The issues are pointed out as follows:

- Study of impact on surrounding beaches due to sand extraction and necessity of EIA
- Peripheral people's understanding and approval in terms of sand extraction from a technical point of view
- Application procedure as special exception against ban of sand extraction on the lagoon
- Establishment of implementation system and cost burden from sand extraction to filling

Source: JICA Expert Team

Figure 5.4.6 Transition of Sedimentation in Lagoon at Pt. d'Esny

c. Case-C : Potential of use of dredged sand as material for beach nourishment to other beaches and issues (e.g. Ile aux Cerfs)

Sand dredging in the lagoon at priority coasts was carried out at the channel between Ile aux Cerfs and Ile de I'Est as a blocking measure. In this area, the dredging was carried out twice, approx. 20,000 m^3 in October 2012 and approx. 3,300 m^3 in May 2014 and the dredged material was filled in a nearby erosion area and stocked on the island. It is necessary to regularly and continuously dredge as a measure against blocking of the channel since the volume of sand supply from offshore is remarkable as compared with other beaches. It is assumed that annual sedimentation volume is approx. 1,500 m^3 on average. It is predicted that some problems to be solved will be pointed out such as securing the stock area for dredged material and disposing the material from a long-term view point. It is expected that the dredging sand will be used effectively as a material for beach nourishment or maintenance of other beaches that cannot keep a sediment budget balance (Mon Choisy, Pte. aux Cannoniers and Albion) in order to solve the issue of disposal of dredged sand as an approach to comprehensive beach management in Mauritius. However, the use of the dredged material for other beaches in Mauritius has not actually been realized. To carry out this, some issues are pointed out such as sufficient discussion between lessee and public sectors, review of institutions, clarification of cost allocation, establishment of organization/structure under cooperation between the public and private sector. The concrete issues are as follows:

- Discussion and acceptance for use of dredged material for other beaches between lessee and public sectors
- Establishment of institution for moving sand to other beaches

- Clarification of cost burden
- Establishment of implementation system under cooperation between the public and private sector

Source: JICA Expert Team

Figure 5.4.7 Dreading area at Ile aux Cerfs

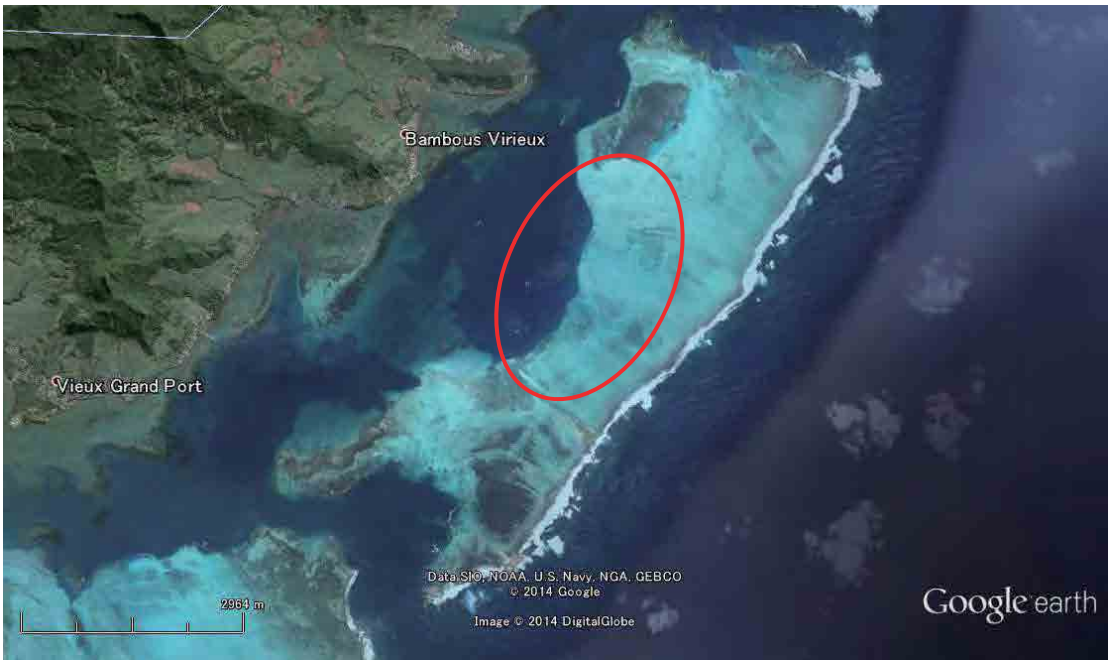
d. Case-D : Potential use of surplus sand on the Lagoon which does not contribute to sand supply to the beach and issues (e.g. Ile aux Phares : opposite Bambous Virieux)

A huge amount of sand has accumulated in the lagoon off Bambous Virieux at north area of Pte. d'Esny and corals hardly exist at the area. The sand supply from offshore to the beach is interrupted because of the presence of a deep channel of approx. 30 m between the reef and the shoreline. A huge amount of sand is being deposited in this deep channel on the west side of the lagoon and the sand is not supplied to the beach on the west of the lagoon. If the sand is taken from this area, it is predicted that there is little possibility of beach erosion and environmental impact because coral cover in the lagoon is negligible. It is thought that the extraction of sand at this area has high potential because huge amounts of sand are always supplied from offshore. However, extraction of sand was banned in 2001, as mentioned above. It is necessary to modify regulations decided by cabinet meeting if sand extraction is carried out in the lagoon. In addition, it is very important to limit the use of extracted sand, for example, use for beach maintenance and conservation only. If the purpose of sand extraction is not limited, there is a possibility to repeat over-extraction of sand leading to coastal ecosystems degradation and beach erosion as was the case prior to the ban in 2001. It is necessary to review the legal system and establish new regulation through sufficient discussion among institutions concerned. The concrete issues are as follows.

- Impact on surrounding beaches due to sand extraction and necessity of EIA
- Application procedure for special exception from the ban on sand extraction in the

lagoon

- Establishment of implementation system and cost burden from sand extraction to nourishment
- Enhancement of observation of sand extraction and continuous environmental monitoring
- Information of appropriate sand grain size for beach nourishment



Source: JICA Expert Team

Figure 5.4.8 Offshore Lagoon at Bambous Virieux

Source: JICA Expert Team

Figure 5.4.9 Seabed Condition at the Lagoon

e. Case-E: Potential of use of sand deposited into deep areas such as reef gaps and issues (sedimentation sand around lagoon)

In order to plan the future removal of sand, the seabed material survey was conducted by MOI at three places: offshore of Flic en Flac, Trou aux Biches and Mon Choisy. The survey

was carried out in order to identify sites where sand has accumulated. This sand may be used for beach maintenance in the medium and long terms because it is considered to be difficult to secure sufficient amounts of sand on land in the future. According to the survey results at the moment, the following issues are noted: potential sand volume is approx. 35,000 m^3, information of sand quality such as grain size, composition, etc., is unclear, water depth of sampling places varies widely between 3 m to 17.5 m and there is a possibility of impact on coral and moving limits for moving sand at place less than 15 m in depth. Therefore, it is necessary to carry out an extensively detailed investigation in order to secure good quality sand stably and efficiently in the future. The concrete issues are as follows:

- Implementation of large-scale potential sand survey off reef areas
- Procurement plan for dredging equipment for sand extraction offshore
- Procurement of dredged material for stock area considering long-term maintenance
- Establishment of implementation system and cost burden from sand extraction to filling
- Implementation of continuous environmental monitoring during and after construction

Chapter 6

Reef Environment Conservation Plan

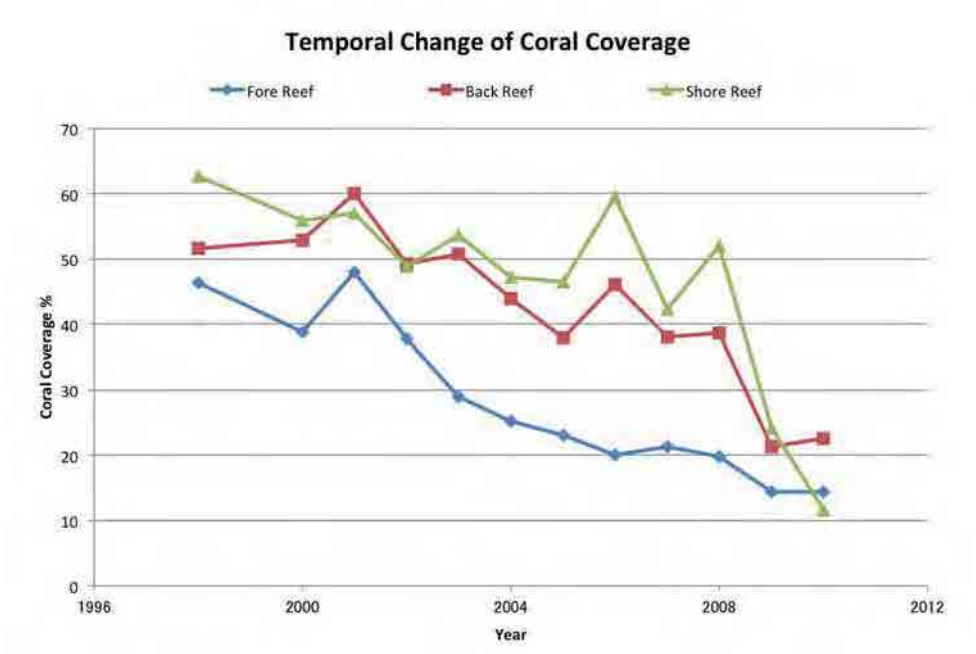
6 Reef Environment Conservation Plan

6.1 Background

The basic policy of Mauritius on conservation of the coastline is to consider the coral reef, lagoon and beach as one system. Following the suggestion by Baird (2003), the system must be conserved and regenerated. This survey, in alignment with this essential way of thinking, lays out plans for conservation of reef environments.

Based on the results of coastlines in this survey using the aerial photographs and satellite photographs, coral, seagrass beds and water quality of reef environments are clearly closely related to beach conservation. Namely, coral communities in a lagoon are not the only source of beach sand but also changes in wave height and course current. Consequently, coral community influences the deposition of sand and erosion of beaches. With regard to the seagrass bed, it also contributes to the reduction of waves and to the stability of fine sediment just off the beach, and its disappearance relates to beach erosion. Coral and sea grass cover are influenced by water quality. Eutrophication in the lagoon causes reduction of coral coverage.

Figure. 6.1.1 shows a long-term decline in coral coverage from surveys carried out by AFRC (See: Vol. 1, Ch. 2 p. 2-82). Evaluation of the coral reef coverage was less than 25 % according to the criteria of the Ministry of Environment, Japan. This means that the coral reef is considered poor (See; Vol. 3, Ch. 3, Table 3.1.1). Furthermore, the assessment is that the coral reefs in Mauritius are at a poor level on average. Consequently, it is possible that a decrease in the supply of beach sand and a reduction of wave height in the future could cause the beach to erode.



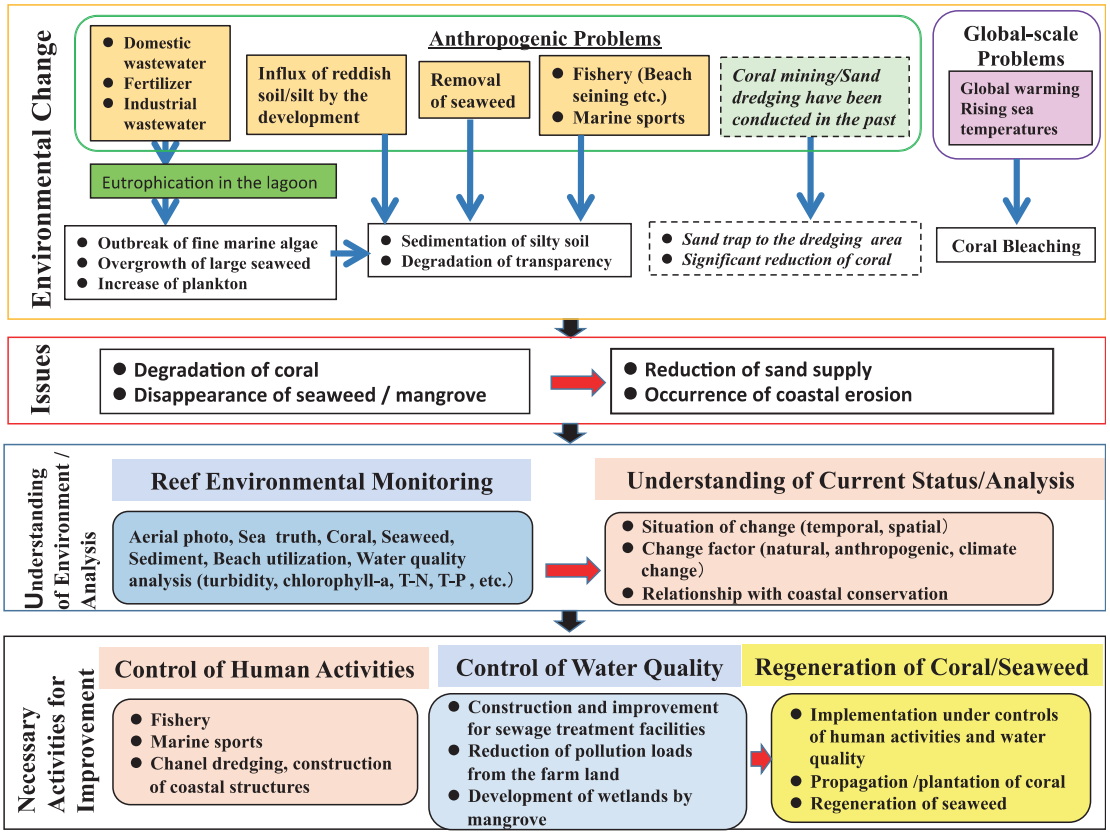
Source: AFRC

Figure 6.1.1 Annual Change in Coral Coverage in Mauritius

The fact that coral coverage has decreased so dramatically as well as other issues mentioned above, show that reef environment conservation is an indispensable factor for preventing beach erosion. Therefore, we discussed the reef conservation plan from this point of view.

The main problems and its measures on the conservation of reef environment relating to disaster prevention of beaches are shown in Figure.6.1.2.

The relationships among components for reef conservation in Mauritius shown in Figure 6.1.2 are not sufficiently clear. The problems pointed out are not based on the results of detailed surveys. Regular monitoring surveys are required. From the results of the monitoring surveys, we looked at the relationships between beach erosion and reduction of the coral community and seagrass bed. Causes of the reduction were also analyzed and consequently plans to each problem are measured.



Source: JICA Expert Team

Figure 6.1.2 Problems and Measures of Reef Environment on Shore Conservation

6.2 Present Conditions of Reef Environment

6.2.1 Coral

As shown in Figure 6.1.1, an average coverage of 50 % in 1998 decreased gradually in all areas; fore reefs, back reefs and shore reefs. By 2010 these figures had decreased to below 25 %. These values of coral coverage are evaluated as “bad or poor” in the benchmark of evaluation by the Japanese Ministry of Environment. Also, the average coverage in the basic survey of this project was 27.2 % and was below the borderline of 30 % as“bad or poor”. It is apparent by these facts that coral reefs in Mauritius are on the way towards long-term decline due to the many causes shown in Figure 6.1.2.

Results of the basic survey carried out from June 2012 to February 2013 are shown in Table 6.2.1. In particular, the Spot Check Method was employed for the 13 target sites. Coral

coverage was 60 %, 30 % and 10 % in Baie du Tombeau, Flic en Flac and Q. Cocos respectively. But, in the other 10 coasts, the coverage was 5 % or below 5 %. Out of the 10 coasts, there was no hard bottom offshore in Mon Choisy and Bel Ombre and these offshores were covered by seagrass beds. The monitoring survey in Grand Sable found the sea bottom was covered by sand or mud, which is not suitable as a coral habitats. Results of the basic survey show coral coverage has a positive relationship to transparency, that is, the coral coverage increases with the transparency in the habitat. Out of the 13 target sites, the transparency was over 10 m in the lagoon of Le Morne, Pte. d'Esny, Q. Cocos Vge and Baie du Tombeau. The highest value of transparency was recorded in Le Morne, but the coverage of living coral was zero. At the monitoring sites, coral skeletons were scattered on the sand bottom, so the coral colonies died several years ago by some factors, possibly including the coral bleaching event in 2003. Also, the coverage of living coral was only 1 % at the central lagoon at Pte. d'Esny, the bottom was covered by sand and there were few living colonies. In contrast, the coral coverage at the back reef was as high as 70 %. There was a reverse relationship between the coverage of living coral and the deposition of silt on the bottom. Namely, if siltation is high, the coral coverage is low. If siltation is high, the photosynthetic activity of coral (zooxanthella) seems to decrease because the sunlight is diminished by the siltation on the colonies.

Table 6.2.1 Features of Corals and Their Habitat Condition in 13 Target Sites

	Target coast	Coverage (%)	Life form	Density (/m²)*	Bottom	Trans**(m)	Siltation
1	Baie du Tombeau	60	Branching/massive	0	Shore reef	10	Low
2	Pte. aux Cannoniers	1	Corymbose	0.1	Shore reef	3	Low
3	Mon Choisy	0		0	Seagrass bed	3	High
4	Bras d'Eau	0		0	Seagrass bed	2	Low
5	Q. Cocos & T. D'Eau Douce	10	Branching/tabular	0	Sand/ patch reef	10	No
6	Ile aux Cerfs	5	Massive/ corymbose	0.5	Rock reef	3	Middle
7	Pte. d'Esny	1	Branching/tabular	0	Sand	10	No
8	Bel Ombre	0		0	Seagrass bed	5	Low
9	Le Morne	0		0	Sand/ coral pebble	15	No
10	Flic en Flac	30	Massive/ branching	0	Sand/ patch reef	5	Low
11	Albion	2	Massive/ corymbose	0.1	Sand/ coral pebble	3	Low
12	Pte. aux Sable	1	Massive/ corymbose	0	Patch reef	3	High
13	Grand Sable	0		0	Mud	1	Very High

* Density of one-year-old juvenile corals (of *Acropora*)

** Visiblity in lateral distance

Source: JICA Expert Team

The density of one-year-old juveniles (genus *Acropora*) was less than one per m^2 in all sites. These densities show that natural regeneration of coral communities is very difficult in all coasts. So, human support, such as coral transplantation, is needed to regenerate coral communities in the lagoons.

Results of the spot-check method carried out from June 2012 to February 2013 and the results of visual observation by a glass-bottomed boat were compared with the charts produced by the Ministry of Fisheries (Mauritius) jointly with Borstad Associates Ltd in 1996 called "Multispectral Imagery of the Mauritius & Rodrigues Coastal Zone". This comparison was done to gauge increases or decreases of seagrass beds and coral communities during these 18 years. The results are shown in Table 6.2.2.

Table 6.2.2 Increase or Decrease in the Area of Coral Communities and Seagrass Beds

	Target Coasts	Area of Living Corals	Area of Seagrass
1	Baie du Tombeau	▼	−
2	Pte. aux Cannoniers	▼	−
3	Mon Choisy	▼	△
4	Bras D'Eau	−	△
5	Q. Cocos & T. D'Eau Douce	▼	−
6	Ile aux Cerfs	−	△
7	Pte. d'Esny	△	−
8	Bel Ombre	△	△
9	Le Morne	▼	△
10	Flic en Flac	▼	△
11	Albion	▼	△▼
12	Pte. aux Sable	▼	▼
13	Grand Sable	▼	−

△: Increase, ▼: Decrease, △▼: Partly increase and partly decrease
− : Absent

Source: JICA Expert Team

The area of coral communities (that is the distribution of coral habitats, not coverage of living coral) decreased in all coasts except for the lagoons at Pte. d'Esny and Bel Ombre. In contrast, the area of the seagrass beds increased in many coasts during these 18 years. Referencing a chart from AFRC taken in 1994, a seagrass bed located at the center of the coast in the lagoon of Pte. aux Sables disappeared in 1996. The seagrass bed of *Halodule* at the north has been slightly increasing in the lagoon of Albion but the seagrass bed in front of AFRC has been disappearing for the past18 years.

6.2.2 Water Quality

Table 6.2.3 shows the summary of water quality in lagoons along the 13 sites covered by the coastal protection plan in accordance with the results of the water quality survey conducted in this study. The table describes the water quality of lagoons and coral coverage for each site as well as the regional characteristics of hinterlands that are sources of water pollution in the lagoons. It explains population density, construction of the sewerage system, location of the river mouth (important in evaluating red soil runoff) and an area of farmland which is important in evaluating the impact of pollutant loads from sugarcane farms.

As described in 2.6.1 of Water Quality Environment in Chapter 2 of the Basic Study, coral coverage tends to decrease exponentially with an increase in concentrations of chlorophyll *a*, turbidity, nitrogen and phosphorus. During the study, high chlorophyll *a* concentration and turbidity were observed at Baie du Tombeau, Mon Choisy, Pointe aux Cannoniers, and Pointe aux Sables where there is either a high population density or a high concentration of hotels and villas. These conditions of coral coverage being 10% or less do not favour the growth of coral, and are slightly unsuitable when the coral coverage is between 10 and 20%. Grand Sable and Bras d'Eau show a low salt content which also has an effect because of the strong influence of rivers.

Wastewater from households (not including villas and hotels that are not connected to the sewerage system) are considered to be the cause of high concentrations of chlorophyll *a* along these coasts.

On the other hand, with respect to Quatre Cocos Village, Trou d'Eau Douce and Île aux Cerfs, whose hinterlands do not have large population centers but include vast sugarcane farms, the water quality of these coasts is relatively good. The runoff of fertilizers and red soil from the sugarcane farms are considered unlikely to exert a direct influence on the coral of these coasts.

The coral coverage of Belle Mare/Palmar where the water quality survey was conducted is as high as 50 to 60%, but it has been reported that algae have been increasing along these coasts in recent years. The growth of algae is particularly remarkable in Palmar. According to the results of the water quality survey in this study, the chlorophyll *a* concentration in Belle Mare/Palmar is 0.48 on average and between 0.21 and 1.79μg/L. Also, judging from the correlation between coral coverage and chlorophyll *a* concentration determined in this study, the average chlorophyll *a* concentration in Belle Mare, which is 0.35μg/L, is considered to be slightly favorable for the growth of corals corresponding to a coral coverage of 20 – 50%. On the other hand, the concentration in Palmar, which is 0.72μg/L on average, is not very suitable for the growth of coral corresponding to a coral coverage of 10 – 20%. It is presumed that the coral coverage in Palmar will rapidly decline if the chlorophyll *a* concentration remains high in the future. The cause of high chlorophyll *a* concentration in Palmar must be the wastewater from the hotels and villas and fertilizer runoff from the farmland in the hinterland of the coast that permeates into the ground and flows into the lagoon.

As described earlier, since the current water quality monitoring has several problems including low accuracy of nutrient salt analysis and lack of T-N and T-P measurements, the eutrophication conditions and water pollution mechanism of the lagoons have not yet been identified. As the first step to reef environmental protection, improving the current water quality monitoring to increase the analysis accuracy is required. After that, efforts should be made to study the impact of pollutant loads that flow into the lagoons through rivers and groundwater and develop measures to control them using the improved water quality monitoring technology.

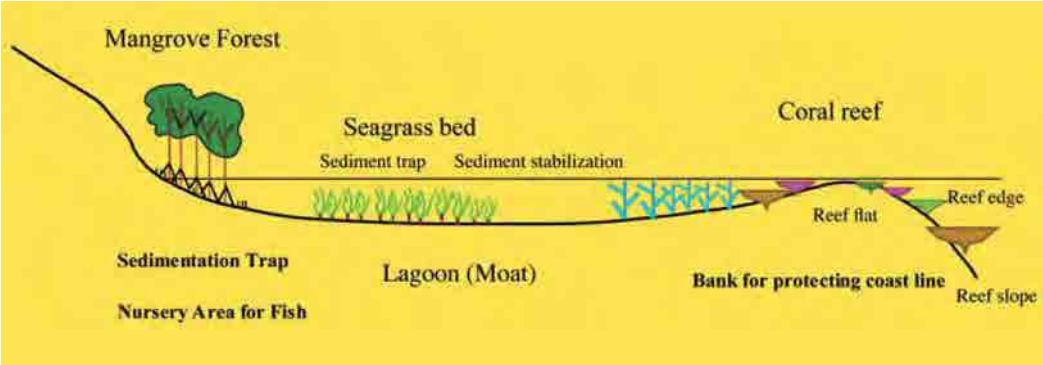
Table 6.2.3 Water Quality of Lagoon, Coral Habitat Conditions and Social Conditions of the Hinterland that Cause the Water Pollution in Target Coasts

Status	Check items	1 Pte aux Cannoniers	2 Mon Choisy	3 Baie du Tombeau	4 Pt. aux Sable	5 Albion	7 Flic en Flac	8 Le Morne	9 Bel Ombre	10 Pte. D'Esny	11 Grand sable	12 Ile Cerf	13 Q. Cocos Vge, T. d'Eau Douce	14 Bras d'Eau
Water quality	Outline of Water quality	In the vicinity of the coast, transparency is 3m and siltation is low. Chlorophyll a is at a level that is not well suited as a habitat of coral (the coverage of living coral is from 10 to 20%). It is in eutrophication state slightly. As the cause, the effects of drainage from the rear houses and villas are considered.	In the vicinity of the coast, transparency is 1m and seaweed is flourishing. Coral is not inhabited. Chlorophyll a is high and at a level that corals can hardly live (the coverage of living coral is less than 10%). It is in eutrophication state. As the cause, the effects of drainage from the rear houses and villas are considered.	Although COD and PO4 was deteriorated from 2001 to 2003, these high concentrations have been no longer detected. Chlorophyll a is high and at a level that corals can hardly live (the coverage of living coral is less than 10%). It is in eutrophication state. As the cause, the effects of drainage from the houses not connected to the sewer are considered.	The water quality in vicinity of the coast is affected by GRNW River. Turbidity and siltation is high. Chlorophyll a is at a level that t is not well suited as a habitat of coral (the coverage of living coral is 10 to 20%.) Coliform is always high. The effects of drainage from the houses not connected to the sewerage system are considered.	Transparency is 3m and siltation is low. Chlorophyll a, turbidity and nutrient salts are generally good level as habitat of coral that the coverage of living coral is 20 to 50%. The water quality is relatively good. Recently, high concentration of coliform has been detected. The water pollution from domestic wastewaters is considered to be progress.	Transparency is 8m at Flic en Flac and 5m at Wolmar near Tamarin River and siltation is relatively low. Chlorophyll a in the vicinity of the coast is generally good level as habitat of coral that the coverage of living coral is 20 to 50%. Coliform is relatively low state.	At Le Morne, transparency is 15m and siltation is not. At nearby Ile aux Benitiers, transparency is 5m and siltation is a moderate. Chlorophyll a in the vicinity of the coast is generally good level as habitat of coral that the coverage of living coral is 20 to 50%.	Chlorophyll a, turbidity and nutrient salts are generally good level as habitat of cora that the coverage of living coral is 20 to 50%. As for the water quality of river, especially NO3 concentration in a small rever is several times higher thaa that in the laggon. The pollution loads from the river is less because the river flow is less.	Transparency is 10 to 15m and siltation is not. Chlorophyll a, turbidity and nutrient salts are good level as habitat of coral that the coverage of living coral is more than 50%.	Under the influence of rivers at both ends of the coast, transparency is 1m and siltation is very high. Chlorophyll a and turbidity in the vicinity of the coast are at a level that it is not well suited as a habitat of coral (the coverage of living coral is less than 10%).	In the offshore lagoon, chlorophyll a, turbidity and nutrient salts are generally good level that the coverage of living coral is 20 to 50%. In the water area between the islets and the main island, the water is easily stagnant. When the channel will be closed by the accumulation of sand, the eutrophication will be progress.	Transparency is 5 to 10m and siltation is low. Chlorophyll a, turbidity and PO4 of nutrient salts are generally good level as habitat of coral. However, NO3 is at a level that it is not well suited as a habitat of coral. As the cause, the effects of drainage from the rear marshes and houses are considered.	Under the influence of river in the closed-off section of bay, salinity in vicinity of the coast is low. Chlorophyll a in the vicinity of the coast is at a level that it is not well suited as a habitat of coral (the coverage of living coral is from 10 to 20%). As the cause of high chlorophyll a, the effects of input flow from the river are considered.
	Chlorophyll a (ug/L)	086 (*)	1.60(*)	1.74(*)	0.33-1.20(#) (Ave. 0.63)	0.23-1.50(#) (Ave. 0.51)	0.50(*)	0.25-0.58(#) (Ave. 037)	0.00-0.85(#) (Ave. 0.37)	0.05-0.12(#) (Ave. 0.08)	1.65-2.24(*) (Ave.1.76)	0.10-0.93(#) (Ave. 0.39)	0.22-0.97(#) (Ave. 0.50)	0.86(*)
	Turbidity (NTU)	-	-	-	1.07-9.05(#) (Ave. 2.28)	0.44-2.30(#) (Ave. 0.95)	-	0.11-1.10(#) (Ave. 0.66)	0.00-1.24(#) (Ave. 0.88)	0.16-0.43(#) (Ave. 0.30)	3.26-16.5(*) (Ave.10.5)	0.38-2.09(#) (Ave. 1.18)	0.40-3.37(#) (Ave. 1.06)	1.13(*)
	NO3-N (mg/L)	-	-	-	<0.01-0.07(#) (Ave. 0.04)	<0.01-0.04(#) (Ave. 0.03)	-		<0.01-0.05(#) (Ave. 0.04)	<0.02	-	<0.01-0.04(#) (Ave. 0.03)	0.03-0.17(#) (Ave. 0.08)	-
	PO4-P (mg/L)	-	-	-	<0.005-0.01(#) (Ave. 0.007)	<0.005-0.01(#) (Ave. 0.008)	-		<0.005-0.02(#) (Ave. 0.008)	<0.005	-	0.006-0.02(#) (Ave. 0.010)	<0.005-0.04(#) (Ave. 0.015)	-
Population	Population Density (per km2)	794	794	**1,964**	**2,946**	298	104	60	58	682	435	512	552	299
Sewerage disposal behind coast	Status of development of sewerage facilities behind coast	Sewerage Systems(Trunk Sewer), Absorption Pit, Septic Tank, Pit Latrine	Sewerage Systems(Trunk Sewer), Absorption Pit, Septic Tank, Pit Latrine	Sewerage Systems(Trunk Sewer), Absorption Pit, Septic Tank.	Sewerage Systems(Trunk Sewer), Absorption Pit, Septic Tank, Pit Latrine	Absorption Pit, Septic Tank, Pit Latrine	Absorption Pit, Septic Tank, Pit Latrine	Absorption Pit, Septic Tank, Pit Latrine	Absorption Pit, Septic Tank, Pit Latrine	Absorption Pit, Septic Tank, Pit Latrine	Absorption Pit, Septic Tank, Pit Latrine	Absorption Pit, Septic Tank, Pit Latrine	Absorption Pit, Septic Tank, Pit Latrine	Absorption Pit, Septic Tank, Pit Latrine
	Present condition of sewerage disposal from houses (Sewerage system, Septic tank, Pending arrangement, etc.)	Grand Baie VCA: SS: 114 AP: 291 ST: 974 PL: 7	Grand Baie VCA: SS: 114 AP: 291 ST: 974 PL: 8	B.DuTombeauVCA: SS: 3422 AP: 414 ST: 82	Town of PlouisVCA SS: 2215 AP: 997 ST: 236 PL: 33	Albion VCA: SS: NIL AP: 754 ST: 1303 PL: 55	Flic en Flac VCA: SS: NIL AP: 1294 ST: 1975 PL: 6	Le Morne VCA: SS: NIL AP: 148 ST: 156 PL: 107	Bel Ombre VCA: SS: NIL AP: 676 ST: 36 PL: 25	Beau Vallon VCA: SS: NIL AP: 1461 ST: 36 PL: 113	Grand Sable VCA: SS: NIL AP: 997 ST: 136 PL: 116	T. D' Douce VCA: SS: NIL AP:1470 ST: 115 PL: 28	T. D' Douce VCA: SS: NIL AP:1470 ST: 115 PL: 28	P. de Flacq VCA: SS: NIL AP: 2389 ST: 21 PL: 119
	Present condition of sewerage disposal from hotels and restaurants (Sewerage system, Septic tank, Pending arrangement, etc.)	Hotels >75 rooms uses onsite treatment plants.Restaurant uses septic tanks.	Hotels >75 rooms uses onsite treatment plants.Restaurant uses septic tanks.	Hotels >75 rooms uses onsite treatment plants.Restaurant uses septic tanks.	Septic tanks, Absorption pits	Hotels >75 rooms uses onsite treatment plants.Restaurant uses septic tanks.	Hotels >75 rooms uses onsite treatment plants.Restaurant uses septic tanks.	Hotels >75 rooms uses onsite treatment plants.Restaurant uses septic tanks.	Hotels >75 rooms uses onsite treatment plants.Restaurant uses septic tanks.	Hotels >75 rooms uses onsite treatment plants.Restaurant uses septic tanks.	Septic tanks, Absorption pits	Hotels >75 rooms uses onsite treatment plants.Restaurant uses septic tanks.	Septic tanks, Absorption pits	Hotels >75 rooms uses onsite treatment plants.Restaurant uses septic tanks.
	Development plan of sewerage system for houses and hotels behind coast	Sewerage Systems Completed Phase 1 in Year 2010.	In pipeline for development, Study stage	Sewerage Systems Completed in Year 2010	NIL	In pipeline for development, Study stage.	In pipeline for development, Study stage.	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Impact of pollution load from sugarcane	Incidence of red-soil runoff from land side	None	None	Yes. River Mouth. Reef Dist: 1.7Km	None	Yes. River Mouth Lagoon Width: 483m	Yes. River Mouth Lagoon WIdth: 446m	None	Yes. River Mouth Lagoon Width: 832m	None	None	Yes. River Mouth Lagoon Width: 1.9Km	Yes. River Mouth Lagoon Width: 2.4Km	None
	Existence of sugarcane field behind coast. If there is it, area of the field behind coast.	Yes. Area: 678 Ha	Yes. Area: 678 Ha	Yes. Area: 118 Ha	None	Yes. Area: 2,907 Ha	Yes. Area: 1,635 Ha	None	Yes. Area: 373	Yes. Area: 478 Ha	None	Yes. Area: **10, 854** Ha	Yes. Area: **10, 854** Ha	None
Coral reef	Coverage of living corals	1%(*)	0%(*)	60% (*:Port Chambly) 30% (Back Reef)	0-1% (#) 60% (Petti Verger)	1-33%(#)	30-60%(#)	10-70%(#)	0-50%(#)	1-70%(#)	0%(*)	0-70%(#)	1-90%(#)	0-20% (#)
	*: Observation for water quality and coral reef was conducted close to shore #: Observation for water quality and coral reef was conducted from the shore to the reef edge.													
	SS: Sewerage Systems Ap: Absorption Pit. ST: Septic Tank PL: Pit latrine													

Source: JICA Expert Team

6.2.3 Conservation of Coastal Area and Reef Environment

From the viewpoint of basic knowledge and case studies in Mauritius, the conservation of the reef environment is important, especially for coral and water quality. After looking at and grasping the various problems of coastal erosion and reef environment conservation, we decided our measures for the plan for conservation of reef environment



Source: JICA Expert Team

Figure 6.2.1 General Structure of Coastal Ecosystem in Tropical and Subtropical Regions

Generally, the coastal ecosystem comprises three components, namely coral reefs offshore, mangrove forests along the beach (if there is no mangrove forest, a rocky shore or a sandy beach are developed) and seagrass beds in lagoons. Coral reefs offshore are geographically divided into reef flat, reef edge and reef slope (Figure 6.2.1). These three components were thought of as independent ecosystems until now. However, from the viewpoints of biological and water exchange systems, these three components are considered a unified ecosystem. Coral reef offshore diminishes the energy of waves from the open sea (Ferrario, 2014), and protects mangrove forests, sand beaches along the coastline and seagrass beds in the lagoon. In contrast, mangrove forests have a function to stop soil and rock from land, and seagrass beds trap particles in the water column. Coral reefs offshore are given an adequate habitat by their functions (such as filtering and stabilization of sediment). In this way, these three components seem to have a relationship of interdependence.

Coral sand on the beach is supplied from living coral reefs offshore and is deposited. Coral sand produced physically at the fore reef or produced through the feeding process by parrot fish (Bellwood, 1995 & 1996) is carried and deposited on a beach, partly comes back offshore through a passage. According to the balance sheet on coral sand in target coasts in the basic survey, sand deposited on the beach of Mauritius was estimated at ca. 500,000 m^3 in total during 45 years from 1967 to 2011. Ocean wave heights decrease to 10 % at the reef edge, and the wave heights diminish more and more through the reef flat and lagoon before the waves hit the beach. Therefore, wave height at the beach is not so large.

a. Erosion, deposition and coral

As shown in Figure 6.2.2, there was no remarkable change in the coastline at south Le Morne in the aerial photo of 1967. A tongue-like beach deposited offshore with a width of 200m. The tongue-like beach appeared with the development of a coral community just outside this beach as shown in Figure 6.2.2. The satellite photo was taken in 2008. Current marks on the bottom at this point show that the shore current goes from offshore to the beach, then turns and is divided into two directions, i.e. north and south. There was no shallow area in 1967. Deposition of sand on the beach seemed to be advanced by the movement of sand from offshore to the beach and by the diminishing effect of the shallow area with the development of the shallow area.

Left aerial photo in 1967, Right satellite photo in 2008

Figure 6.2.2 Change in Beach with Shallow Area Offshore:

From a survey conducted using a glass-bottom boat, it became clear the shoal is made of a dense patch of branching coral. From this we concluded that the development of coral community seems to promote the deposition of sand on the beach.

On the other hand, a part of the beach is eroded with coral patches disappearing offshore in Flic en Flac and Q. Cocos lagoons.

b. Erosion and seagrass

The beach was maintained with a long shoal off the beach in the aerial photo taken in 1967 at Trou aux Biches. But, the long shoal disappeared in the satellite photo taken in 2008 and a part of the beach was eroded back to 100 m. Dr. Bhagooli, University of Mauritius, surmised that the shaded area seemed to be seagrass beds. However, the shoal still appears in the north area of the eroded coast and the beach has been maintained with no change.

Left an aerial photo taken in 1967, Right a satellite photo taken in 2008

Figure 6.2.3 Changes in the Shape of Beach with the Change of Shoal at Trou aux Biches:

Left an aerial photo taken in 1967, Right a satellite photo taken in 2008

Figure 6.2.4 Changes in the Shape of Beach with the Shoal Offshore in Albion:

The same change as Trou aux Biches was seen in Albion. A shoal of seagrass beds was seen in the south beach and bottom marks showing the movement of sediment and s were seen from offshore to the edge of a seagrass bed in the aerial photo in 1967. The marks were seen along the edge of the seagrass beds and changed direction to offshore. In contrast, the shoal disappeared and beach erosion occurred as can be seen from the satellite photo in 2008. By these examples, shoals of seagrass beds and living coral communities contribute to protect the beach, especially by diminishing wave energy and depositing coral sand.

In the lagoon of Pte. aux Sables, the seagrass bed just offshore of the central beach disappeared and beach erosion has occurred.

c. Erosion, deposition and mangrove

In Bras d'Eau, the central beach has eroded and sand was deposited at the west point of the beach. A mangrove forest was seen offshore of the central beach in the aerial photo in 1967, but the mangrove forest cover at Bras d'Eau has decreased. The erosion of the central beach seems to be related to the decrease of the mangrove forest cover.

d. Summary

It becomes clear that changes in the biological components, namely coral, seagrass and mangrove cover as shown in Figure 6.2.1, are related to erosion and deposition of sand on beaches. In particular, coral is not only a resource of coral sand depositing on the beach, but also has a function to stabilize the beaches. Therefore, for analyzing the dynamics of the coastline, we need to monitor not only the physical process but also to pay attention to these biological components.

6.3 Issues of Reef Environment

6.3.1 Basic Materials

a. Chronological changes

In examining the measures to protect the reef environment, it is very important to implement inventory surveys of each element comprising the reef environment such as coral, seaweed, mangroves, bottom sediment, water quality, shoreline location, land use of hinterland and then to quantify the chronological changes of each element. These surveys consist of remote sensing based on satellite images and aerial photographs as well as on-site confirmation survey by direct measurement, namely by sea truth. However, in Mauritius, inventory information covering the entire country and its chronological information has hardly been developed. Also, conventional inventory information is based on surveys at very limited points. With respect to coral and seaweed, the organizations described below have conducted inventory surveys.

Table 6.3.1 Existing Inventory Study on Coral and Seagrass Conducted in Mauritius

Age of Inventory Survey	Implementing Organization
1994	AFRC
1996	CACI
2008	ESA

Source: JICA Expert Team

In 2008 and in 2012 inventories were again carried out for Balaclava and Blue Bay Marine Parks respectively.

It is necessary to regularly conduct remote sensing by aerial photography from helicopter or drone and by satellite photography, and on-site surveys, that is sea truth to collect and organize chronological information on various inventories.

b. Water quality indicators

Since 1995, the ministry responsible for fisheries has had an on-going long term coastal water quality monitoring programme for the following parameters: total coliform, fecal coliform, pH, salinity, temperature, dissolved oxygen, chemical oxygen demand, nitrate, nitrogen and phosphate. Processed data is submitted to the MOESDDBM for drafting reports.

In order to evaluate the water quality of the lagoons in Mauritius in 2011 MOESDDBM established the lagoon water quality index along with all the stakeholders with the support of the EU. The water quality indicators are based on the existing method of water quality monitoring conducted in lagoons. This method classifies existing water quality parameters into biological parameters such as coliform, fecal coliform, and enterococcus and physicochemical parameters such as pH, salt content, temperature, DO, NO_3, PO_4. Then each parameter is evaluated on a scale of five; Excellent, Good, Sufficient, Poor and Bad. After that, final assessment in the five scales is provided by comparing the assessment results of these parameters. As for the standards to assess these parameters, Class A2 for conservation of natural areas in Category A for the conservation section of the Guidelines for Coastal Water Quality (General Notice No. 620 of 1999) of Mauritius shown in Table 6.3.2 is used.

Table 6.3.2 Guideline for Coastal Water Quality Mauritius

CATEGORY		A Conservation		B Recreation		C Fisheries		D Industrial
Class		A1 Coral Community	A2 Natural Areas	B1 Primary Contact	B2 Secondary Contact	C1 Aqua-culture	C2 Shellfish	D Industrial & others
Parameters	Unit							
pH	-	7.5-8.5	7.5-8.5	7.5-8.5	7.5-8.5	7.0-8.5	7.0-8.5	7.0-9.0
Temperature	^{0}C	ambient	ambient	ambient	ambient	ambient	ambient	ambient
Suspended Solids	mg/l	5	5	5	10	15	15	15
Dissolved Oxygen	mg/l	>5	>5	>5	>5	>5	>5	>2
Chemical Oxygen Demand[1]	mg/l	2	2	3	3	5	5	5
Total Coliforms	CFU[3]/100 ml	1000	1000	1000	5000	1000	70[2]	---
Faecal Coliforms	CFU/100 ml	200	200	200	1000	200	14[2]	---
Nitrate-Nitrogen	mg/l	0.2	0.3	0.8	0.8	0.8	0.8	1.0
Phosphate	mg/l	0.04	0.05	0.08	0.08	0.08	0.08	0.1

1 by alkaline potassium permanganate method
2 organisms per 100 ml by MPN method
3 CFU: Colony Forming Unit

Source: [Guidelines for coastal water quality] General Notice No. 620 of 1999

However, with respect to this method of water quality assessment in lagoons, the final assessment is greatly affected by the judgment results of biological parameters because the standards for physicochemical parameters are too stringent. As such, this method basically only determines whether or not the water is safe enough for swimming.

Water quality assessment of the reef environment should naturally involve the assessment of safety as a swimming area, but it is also important to evaluate the water quality from the viewpoint of protecting the coral reefs and other ecosystems. In this regard, the current method is not enough to give an assessment in relation to the protection of coral reefs.

As described earlier with respect to the basic study, water quality parameters that have a strong correlation with the growth of corals and coverage are chlorophyll *a*, turbidity, nitrate as nitrogen (NO_3-N) and phosphorus (PO_4-P). In particular, chlorophyll *a* and turbidity should be included in the monitoring parameters of coastal waters as soon as possible since it is relatively easy to measure them. Also, deterioration of corals in accordance with water quality degradation by eutrophication has occurred at concentration levels lower than the values specified in the Guidelines for Coastal Water Quality of Mauritius (Class A1 – Conservation of coral community).

Consequently, in order to adequately evaluate the growth environment of coral in lagoons based on the water quality, it is necessary to add chlorophyll *a* and turbidity to the water quality monitoring parameters and improve the analysis accuracy for nutrient salts (NO3, PO4). Incidentally, like turbidity, transparency is a parameter that helps to determine the cloudiness in water and it would be effective to measure it in addition to turbidity.

c. Causal relationship

As described earlier, if water quality monitoring is implemented while keeping the current analysis accuracy as it is, the relationship between the deterioration of corals and eutrophication will not be able to be identified. It is necessary to implement water quality monitoring at an analysis accuracy equivalent to that of the water quality survey conducted in this study as shown in Table 6.3.3.

Table 6.3.3 Comparison of Analysis Accuracy for Monitoring Parameters in Lagoon

Parameter	Unit	Detection limit for existing monitoring by AFRC	Detection limit by this study
NH_4-N	mg/l	-	0.01
NO_3-N	mg/l	0.1	0.01
NO_2- N	mg/l	-	0.005
T-N	mg/l	-	0.01
PO_4-P	mg/l	0.01	0.005
T-P	mg/l	-	0.005
Chlorophyll-a	ug/l	-	0.1

Source: JICA Expert Team

However, the water quality survey in this study was carried out only twice (in December and June) in the lagoons along eight coasts. Also, for the five sites out of the sites covered by the coastal protection plan (13 sites) for which a water quality survey has not been implemented, the survey was conducted mainly to measure the chlorophyll *a* concentrations using a multi-parameter water quality meter. Therefore, it is necessary to conduct further studies to see if the correlations obtained in this study are applicable to all lagoons in Mauritius throughout the year.

River water quality monitoring has conventionally been carried out for major rivers, but as is the case with seawater quality monitoring, the analysis accuracy is low for some of the parameters (COD, NO_3). Also, with respect to nitrogen and phosphorus, T-N and T-P are not measured. As such, the total inflow of nitrogen and phosphorus into lagoons through rivers is not identified. It is also necessary to improve the method of water quality monitoring with respect to monitoring river water.

The deterioration of coral is caused by human activities, such as eutrophication, natural phenomena, such as cyclones and floods, and climatic changes, such as bleaching. The impact of each of these causes has not yet been quantified. To quantify such impact, it is necessary to establish a comprehensive monitoring system consisting of spot monitoring of the water quality, coral and other ecosystems in lagoons as well as planar monitoring using aerial photographs and satellite images.

d. Corresponding organizations

It is necessary to regularly conduct remote (planar) survey by aerial photography from helicopter and on-site survey by sea truth to collect and organize chronological information on various inventories.

For the protection of the reef environment, it is necessary to establish a structure in which water quality management of the land, including river water and groundwater, and water quality management of the sea are linked together. To establish such an integrated structure, results of water quality monitoring conducted by relevant organizations have been put together and compiled into an environmental report in the Environmental Audit under the initiative of MOESDDBM. Also, as described earlier with respect to water quality indicators, a project on water quality indicators of lagoons has been jointly implemented by the AFRC and the NEL under the initiative of MOESDDBM.

However, as described above, the current water quality monitoring of the land and the sea has only a few parameters in common and the analysis accuracy is low for some parameters. As such, the inflow quantity of pollutants from the land such as nitrogen and phosphorus, the extent of pollution in the sea and the progress of lagoon eutrophication have not been sufficiently identified. In monitoring the water quality of the land such as groundwater, river water and sewage effluent, it is necessary for each relevant organization to adopt the same parameters as those for lagoons with respect to nitrogen and phosphorus, particularly for the purpose of controlling the eutrophication of lagoons.

Since the structure to promote collaboration between the organizations relating to each ministry and agency in water quality management has mostly been established, it is expected that when common parameters in water quality monitoring implemented by each organization increase, common understanding of the impact of pollutant loads from the land will be promoted and a structure for collaboration will be strengthened. However, inadequate communication of information with the local residents and hotels is perceived as a challenge for the future.

e. Practice of measures

The “ICZM Sub Committee on Coral Reefs” comprises representatives from the ministry responsible for fisheries (Fisheries Division), the ministry responsible for the environment (Department of Environment), MOI (Mauritius Oceanography Institute), University of Mauritius, National Coast Guard, Beach Authority, Wastewater Management Authority, Tourism Authority, NGOs and Indian Ocean Commission (IOC). The committee holds meetings regularly. The committee has a role of exchanging information and also has a function to put measures into practice.

The Fisheries Division (AFRC) has been carrying out coral plantation at Albion, Pointe aux Sables and Trou aux Biches as a measure of coral rehabilitation since 2011. According to the AFRC report, the survival rate of planted corals was ca. 50 % after 2 years (Figure 6.3.1).MOI also carried out coral plantation at Albion, Trou aux Biches and Flic en Flac (Table 6.3.4).

Table 6.3.4 Coral Plantation by MOI and AFRC

	MOI			Albion Fisheries Research Center		
Year	Albion	Flic en Flac	Trou aux Biches	Albion	Pointe aux Sables	Trou aux Biches
2011	8,000			80		
2012		6,000		80	80	80
2013			3,000		80	80

The unit of number is a piece or flagment of coral.

Source: JICA Expert Team

Source: AFRC

Figure 6.3.1 Coral Farming by AFRC

MOI has completed a study on coral farming. According to the surveys carried out in 2014, the survival rates of planted corals were over 75% at Albion (3 years after plantation), over 65 % at Flic en Flac (2 years after plantation) and over 35 % at Trou aux Biches (1 year after plantation) (Figure 6.3.2). These survival rates are evaluated as good except for that at Trou aux Biches.

Small basal tables made of PVC were set at Albion, Pointe aux Sables and Trou aux Biches in 2010. In 2013, AFRC set five large galvanised iron basal tables with 100 coral fragments at each of the following sites: Balaclava Marine Park, Trou aux Biches. Six hundred coral fragments have been placed in Blue Bay Marine Park. In future plans, the same type of large basal tables will be set at Ile aux Benitiers, Pointe aux Sables, Albion, Bel Ombre and Mon Choisy..

The ministry responsible for the environment also started a coral reef restoration project in 2003 and continues using natural regeneration in Flic en Flac Lagoon (Figure 6.3.3) following the recommendation from Baird (2003) and confirmed the possibility of natural regeneration in some species.

Source: JICA Expert Team

Figure 6.3.2 Coral Plantation by MOI in Flic en Flac Lagoon

Coral plantations by AFRC and MOI were evaluated sufficiently as a pilot project. But considering the present condition of Mauritian coral reefs shown in Figure 6.1.1, coral plantations must be promoted in the future. Participation of the local community and NPO(s) is also needed. In particular, consensus about practical measures and cooperation from various organizations are necessary to carry out effective measures. To carry out these measures smoothly, MOESDDBM will organize a committee for effective measures and cooperate closely with participating organizations.

Source: JICA Expert Team

Figure 6.3.3 Reef Rehabilitation by MOESDDBM in Flic en Flac Lagoon.

6.4 Reef Environment Conservation Plan

6.4.1 Basic Policy

As mentioned above, coral itself is not only a resource for coral sand at beaches, but also for the coral community in lagoons and it affects accretion and/or erosion of beaches. It is also suggested that seagrass beds and mangrove forests contribute greatly to stabilizing the beach. In contrast, coral in Mauritius are on a long-term trend of decline (Figure 6.1.1). We need rapid measures for conserving and rehabilitating coral. Also, seagrass beds and mangrove forests are also facing man-made disasters.

For the measures to the problems, i.e. “decrease in supply of coral sand” and “beach erosion” as shown in Figure 6.1.2, we promote conservation and rehabilitation of coral reefs, seagrass beds and mangrove forests, and establish the reef environment conservation plan.

The main points of the plan:

1. Monitoring surveys for understanding the present conditions of the reef environment

2. Controlling human activities for protecting coral reefs, seagrass beds and mangrove forests, in addition to protecting water quality

3. Planting coral and increasing reef generation/ seagrass beds/ mangrove forest

6.4.2 Monitoring Plan (from Short-term to Medium-term)

a. Ecosystem monitoring plan

Monitoring is carried out periodically at least one year on the distribution of coral communities, seagrass beds, mangrove forests and sand in the lagoon by the aerial photos using a helicopter or drone, by satellite photos and by direct observation using a glass-bottomed boat. The data collected is analyzed by remote sensing techniques and basic information on the distribution of corals etc. is accumulated. From the accumulated data, the present conditions of the reef and chronological changes in the distribution and its size are analyzed. Then, various kinds of problems are picked up and the possible measures to be carried out are discussed. Finally, the results of these measures must be evaluated. After this the results are made public for promoting understanding for related people and for connecting to our measures. At the same time, we accumulate related information on coral, seagrass, mangrove, bottom conditions, development of coastal areas and coastal vegetation.

b. Water quality monitoring plan

As described earlier, the current water quality monitoring has problems in terms of sampling points, method, inadequate analysis parameters and low analysis accuracy. To improve the analysis accuracy, installation of high precision analysis instruments and long-term training in the analysis technique for each parameter are particularly needed. In view of this, training in high precision analysis techniques for seawater should be implemented as a technical cooperation project separate from this project.

With respect to the water quality monitoring to be implemented in the future, a short-term goal should be to implement monitoring of all lagoons, adding chlorophyll a, turbidity and transparency, which greatly affect coral coverage and are easy to measure, to the parameters. As a medium-term goal, a higher precision analysis technique should be acquired for nitrogen and phosphorus in addition to the above-mentioned parameters to implement monitoring of all lagoons.

Water quality monitoring in the future should basically be implemented four times a year (twice in the rainy season and twice in the dry season) and should cover all lagoons as in this study.

Table 6.4.1 Outline of Water Quality Monitoring for Reef Environment Conservation

Item	Method
Sampling depth	Surface: 0.5m below surface,
Water quality parameter	Field measurement: Water Temperature, Salinity, Chlorophyll-a, Turbidity, Transparency, DO, pH Laboratory: NH_4-N, NO_2-N, NO_3-N, T-N, PO_4-P,T-N, COD, Chlorophyll-a
Location	Near the coast, on the patch reef and around the reef edge (same as the coral monitoring sites)
Frequency	Four times a year (rainy season: 2 times, Dry season: 2 times)

Source: JICA Expert Team

6.4.3 Human Activity Regulation Plan (from Short- term to Long-term)

a. Regulations of human activity on the coral reef

Fishing activities and nautical activities are prevalent in the lagoon, and the Ministry of Fisheries and the Ministry of Tourism/Tourism Authority control these activities respectively. The effect of these controls is monitored, and the controls are evaluated and improved by the results of the monitoring survey. For fishing activities, the period of fishing, the fishing area and the fishing method are controlled. Regarding tourism, the swimming area and the cruising area, etc. are already set and controlled. However, these effects are not always made clear. Dredging of boat passages which is a scheduled activity under EPA 2002 has been carried out in the lagoon between 2000 and 2006. Such regulations need to be reviewed and updated. The ministry responsible for fisheries started a voluntary buy-back for large net fishing against payment and may envisage total phasing out of this fishing method.

b. Water quality regulations and their improvement

For the purpose of water quality regulation, MOESDDBM has enforced a drainage standard, drainage permit system, water quality guidelines, etc.. With respect to the water quality guidelines, in particular, as described earlier, it became clear that the deterioration of coral in Mauritius has occurred at concentration levels substantially lower than the values specified in the Guidelines for Coastal Water Quality of Mauritius (Class A1 – Conservation of coral community), that is, less than 0.2mg/L for NO_3-N and less than 0.04mg/L for PO_4-P. It is necessary to review the water quality guidelines in the future.

With respect to the water quality guidelines (water quality objectives) for the conservation of coral reefs, guideline values have been reported for the sea of Okinawa in Japan, the Caribbean Sea in Latin America and the Great Barrier Reef in Australia.

Table 6.4.2 shows these guideline values as well as the results of the water quality survey in this study. Comparison of the values in this table shows that the guideline values obtained in this study are mostly the same as the other values that have been reported.

Table 6.4.2 Reported Water Quality Guidelines (draft) for Coral Reef Conservation

Water Quality Parameters	**Unit**	**Location of Coral Reefs**				
		Mauritius		**Okinawa**	**Caribbean**	**Great Barrier**
		Existing guideline	**This study***	(1)*	(2)#	(3)@
Chlorophyll-a	ug/L		**<0.2**	-	<0.1-0.5	<0.45
Turbidity	NTU		**<0.5**	<0.11	-	-
Transparency	m		**-**	>14	-	>10
T-N (mg/L)	mg/L		**-**	<0.08	-	-
T-P (mg/L)	mg/L		**-**	<0.01	-	-
NO3-N+NO2-N+NH4-N	mg/L	<0.2	**<0.012**	<0.01	<0.014	-
PO4-P	mg/L	<0.04	**<0.007**	<0.006	<0.006-0.009	-

*: This guideline was defined as the water quality value required to maintain 50% of coral coverage.
#: This guideline was defined as the water quality value (the threshold of eutrophication) that the conflict between corals and algae starts.
@: This guideline was defined as the water quality value (the biotic trigger values) that the coral richness (the number of coral species) starts to drop sharply.
Source:

(1): Kinjyo et ai. (2011): Present conditions of nutrient concentration and water turbidity on coral reef areas and their effects on the living coral. Presentation abstract (in Japanese), 14th Annual Conference, The Japanese Coral Reef Society

(2): Mutti and Hallock (2003): Carbonate systems along nutrient and temperature gradients; some sedimentological and geochemical constraints. Int. J. Earth Sci. 92, 465-475

(3) Glenn De'ath and Katharina Fabricius (2008): Water Quality of the Great Barrier reef : Distributions, Effects on Reef Biota and Trigger Values for the Protection of Ecosystem Health, Research Publication No.89, Great Barrier Reef Marine Park Authority

Water quality guidelines are generally "standards that are desired to be maintained" and they provide administrative policy objectives. The guidelines have not been made to determine the minimum limit to be maintained, but they set the objectives to be maintained proactively, aiming to ensure that they will be maintained. With respect to waters where pollution is not advancing at present, it is necessary to set appropriate water quality guidelines in order to at least prevent the situation from worsening. Also, it is favorable to clearly define the waters for which protection of coral and other natural environments should be the priority and those for which recreational or fishery use should be focused on. After that, appropriate guideline values should be set in accordance with the usage of the waters.

The draft guideline values for the protection of coral reefs determined in this study need to be scrutinized in the future after implementing water quality monitoring at a higher accuracy. It

would also be necessary to clearly distinguish between the waters that should protect corals and the waters which should promote other uses should as a priority.

6.4.4 Water Quality Improvement Plan

a. Countermeasures against eutrophication (countermeasures to reduce nitrogen and phosphorus inflow)

Sources of pollution on land were classified into point sources and non-point sources as non-specific pollution sources for the estimation of the nitrogen and phosphorus pollution loads. The point sources were further divided into household, tourism, industrial and livestock-farming pollution sources. Farming land was considered as the non-point source in the estimation. Especially, the load resulting from the runoff of fertilizer from sugar cane fields which occupy approx. 40% of the total land area of Mauritius was considered to be a major pollution load from non-point source, namely from dispersed farming land.

Table 6.4.3 shows the estimation results of the pollution loads for total nitrogen and total phosphorus generated on land. Most of the pollution load from each source either flows into a main stream of a river through a small channel or a branch river or is infiltrated underground before flowing into a main stream of a river and flows into the sea with groundwater. The estimates in the table are the sums of the two types of loads.

As for the pollution loads for nitrogen and phosphorus generated on land, the households (domestic excretion/wastewater) and the farming lands (the runoff of fertilizer from sugar cane fields) are large pollution sources.

Table 6.4.3 Estimated Pollution Loads for T-N and T-P in Mauritius

Type of Pollution		Breakout	Number	Remarks	T-N (kg/day)	T-P ((kg/day)
Point Source	**Domestic**	Total Population	1,255,000		**5,535**	**703**
		Sewerage	376,500	30% of Total	0	0
		Septic Tank	878,500	70% of Total	5,535	703
	Tourism	Tourist per day	3,600		**19**	**3**
		High-volume hotel	1,800	50% of Tourist; Community Plant	8.1	1.1
		Villa, Apartment	1,800	50% of Tourist; Septic tank	11.3	1.4
	Industry	Sugar, Beer, Food, etc.,	—	Sewerage	-	-
	Livestock				**2,338**	**418**
		Catle (head)	7,200		1,174	151
		Goat (head)	24,800		404	52
		Sheep (head)	1,100		18	2
		Pig (head)	17,413		742	212
Nonpoint Source	**Agriculture**	Sugarcane (ha)	77,400	42% of Total Land	**4,135**	**1,075**
		Newly (ha); 30%	23,220	30% of Fertilizer is runoff	573	496
		Ratoon (ha); 70%	54,180	30% of Fertilizer is runoff	3,563	579
Total					**12,027**	**2,198**

Source: JICA Expert Team

From the results on the estimation of nitrogen and phosphorus pollution loads mentioned above, the following are the countermeasures to be taken against eutrophication in Mauritius:

1. Countermeasures to reduce nitrogen and phosphorus runoff from land

   ① Construction of a sewerage treatment plant and improvement in the sewerage treatment system

- Construction of a large-scale sewerage treatment plant
- Extension of high performance septic tank use

② Countermeasures to reduce pollution load from farming land

- Appropriate use of fertilizer
- Application of organic fertilizer (composting of the load from livestock farming)

2. Countermeasures to reduce nitrogen and phosphorus in the sea areas (lagoons)

① Capacity building in the water quality monitoring

② Development of wetlands in river mouths

Because it takes a very long time to improve the problem of eutrophication with land measures taken against it, rapid improvement (improvement in a ten-year period) of the problem cannot be expected from the implementation of such measures.

Because it takes a very long time to implement the countermeasures to reduce the nitrogen and phosphorus runoff from land such as the sewerage development projects, rapid improvement such as in a ten-year period cannot be expected. Therefore, the water quality improvement plan is divided into immediate efforts represented by the short-term countermeasures and the medium- and long-term countermeasures. Regarding the short-term countermeasures, adding water quality monitoring parameters such as chlorophyll *a*, turbidity, T-N and T-P and strengthening the water quality monitoring by using a highly accurate analysis technique will be conducted. Based on these, the specific area and the cause for deterioration of the water quality will be identified. Meanwhile, for medium- and long-term countermeasures, sewerage development mainly from the reduction of pollution loads from the households will be promoted.

b. Countermeasures against inflow of red soils

The reduction in turbidity or siltation requires the implementation of countermeasures against the inflow of red soils during and after rain, in addition to those against eutrophication. In the case of Mauritius, the discharge from farming land such as sugar cane fields which occupies approx. 40% of the total land area of the country and the land development in coastal areas are considered as large pollution sources.

The following are the countermeasures to be taken against inflow of red soils

1. Countermeasures for the pollution sources on land are the basic countermeasures. (Figure 6.4.1 shows examples of countermeasures against red soil inflow which can be taken on land.)
2. Development of wetland in river mouths is an effective supplementary countermeasure.

The actual conditions of red soil inflow in Mauritius are not clear. Firstly, it is necessary to conduct the monitoring for turbidity and accumulation conditions of red soil in the lagoon in order to identify the specific area that the red soil has become a problem.

Because it takes a very long time to improve the problem of red soil inflow with measures against it taken on land, rapid improvement (improvement in a ten-year period) of the problem cannot be expected from the implementation of such measures. Meanwhile, it is

favorable to advise against the current practice of regular removal of seaweed from the sea in front of hotels because the seaweed beds contribute to stabilization of particulates.

Source: Division of Agricultural Water Use in Okinawa Prefecture

Figure 6.4.1 Examples of Measures against Red Soil Inflow

6.4.5 Plantation Plan of Corals, Seagrass and Mangrove (from Short-Term to Long-Term Measures)

a. Plantation of corals

For restoring degraded coral reefs on a long-term basis, large scale coral plantation must be promoted. For the plantation method, the simple and quick method is adequate, so the asexual reproduction method was selected. That is, a fragment of living coral is directly planted on the reef using underwater glue. If there are donors near the plantation area, this method is very quick and easy. If there is no donor in the same lagoon, another method using sexual reproduction will be tried after a pilot procedure. Taking good water quality and protected areas into account, coral plantation will first be carried out in the Le Morne lagoon.

Branching –type coral community as a donor is observed at high coverage around the protected area. Many fragments of living coral inside the high density area are collected and planted into neighboring areas. During the spawning season, the current flows from south to north, so that planktonic larvae (planula) scatter from south to north with the current. In this way, regeneration of coral communities in Le Morne is very important as a mother population for the resource to supply coral larvae to the northern lagoon.

Plantation of coral is also scheduled in the Flic en Flac lagoon after the plantation in Le Morne. It has been confirmed that several coral communities are dominated by branching *Acropora* as a donor in the Flic en Flac lagoon, and coral plantation, the same procedure used in Le Morne, will be carried out. MOI has already carried out coral plantation at the back reef of the central lagoon and the survival rate (> 65 %) of the planted corals is evaluated as good.

There is no coral community as donor in the lagoon of Albion. We need to make a plan for coral plantation using sexual reproduction.

In the lagoon of Pte. aux Sables, the conditions are not good for coral habitats, but a healthy coral community dominated by branching *Acropora* was confirmed in the south lagoon. There is a possibility that this coral community adapted to such a non-adequate environment, so it is important to carry out test plantation using this community as a pilot measure.

b. Plantation of seagrass

Regarding seagrass, we recommend planting seagrass because seagrass beds function to stabilize fine sediment and protect the beach in the lagoons of Mauritius. A monitoring survey was carried out on species of seagrass, effects on wave reduction and sediment stabilization, as well as suitable conditions for growth. Based on these survey results, an adequate seagrass species for planting has been decided and pilot planting has also been started for examining its application. The area of seagrass beds tends to increase, but seagrass has been removed from the lagoon and is still absent, so we need to report its function in detail.

Seagrass is a seed plant. Up to the present, six species are known in Mauritius. There are generally two methods, namely using asexual reproduction and using seeds. In any case, we recommend starting basic experiments for regeneration (See; Vol. 3, Ch. 3.7).

c. Plantation of mangroves

Plantation of mangroves has already been carried out in several areas by the AFRC, etc.. Presently most mangrove propagations are carried out by NGOs, Force Vives and by members of the community. The Fisheries Division provides technical advice and supervises the plantation of mangroves. Such plantation is also needed at Bras d'Eau for example and other areas as a measure for protecting beaches.

Measures of each target sites were discussed in Vol. 2, so we described generally.

6.5 Systematic Correspondence ICZM to Review Paragraph

The "ICZM "Sub Committee on Coral Reefs" comprises representatives of the Ministry responsible for Fisheries MOI (Mauritius Oceanographic Institute), Univ. of Mauritius, Coast Guard, Beach Authority, Water Management Authority, Tourism Authority, NGO and the Indian Ocean Commission (IOC). The committee holds meetings regularly. The committee has a role of exchanging information and also has a function to put measures into practice. We suggest that this subcommittee also should have roles for analysis and discussion on the periodical monitoring data. Additionally, the committee has decision making responsibilities on measures for urgent problems after analyzing like a "Scientific Committee". We also suggest that the ICZM take the initiative in assuming each share of the responsibility among related organizations and carry out specific measures.

Regarding issues like coral bleaching and global climate change, measures planned only by Mauritius are very difficult to deal with the problem. We need cooperation with international organizations such as the IOC, etc.

Present sensitization activities on the coastal environment and conservation of the reef environment for the stakeholders, local people and young people with related organizations such as the University of Mauritius should be maintained and enhanced.

The reef environment conservation activities should basically be implemented by following organizations.

Table 6.5.1 Procedure of Reef Environment Conservation and Corresponding Roles and Organization

Procedure	Details	Roles of the Government	Main organizations									
			MOESDDBM	MOESDDBM (BA)	MoHL	MoF(AFRC)	MoLG(DC)	MoTL	MMS	MOI	WMA	CWA
Basic study	Beach profile and bathymetric survey	Implementation	✓	✓								
	Coral reef and water quality survey	"				✓						
	Wave and current measurement	"	✓			✓			✓			
Coastal conservation plan	Coastal protection plan	Preparation/ Evaluation	✓									
	Breach use plan	"	✓	✓				✓				
	Land use plan	"	✓		✓							
	Environment conservation plan	"	✓			✓						
	Consensus building	Implementation	✓									
Management and maintenance	Monitoring of beach profile and bathymetry[*1]	Implementation, evaluation and feedback to the plan	✓	✓	✓					✓		
	Maintenance and monitoring of coral reef	"	✓			✓						
	Monitoring of water quality	"	✓			✓					✓	✓

*1 Lessee is responsible for leased area, *"MOESDDBM" without special note generally means ICZM Div. *": same as above", *DC: District Council, *BA: Beach Authority

Source: JICA Expert Team

6.6 Summary

By the chronological analysis of aerial and satellite photographs of Mauritius, it was suggested that the existence of coral communities, seagrass beds and mangrove forests in lagoons are deeply related with erosion and accretion of the beach. The decline of coral reefs in Mauritius proceeded after 2000 and the general evaluation on coral reefs fell from "good" to "poor". The causes of decline seem to be eutrophication in lagoons, inflow of terrestrial sediment into lagoons, fishing activities, marine sports and human impacts. Also, biological factors such as the Crown-of-Thorns Starfish and the coral bleaching phenomena related to global warming are also listed (Figure 6.1.2)

To respond to these problems, present conditions will be grasped and analysed by the periodical monitoring surveys on reef environment using aerial and satellite photographs, sea truthing and water quality analysis in this conservation plan for reef environment. We suggested an action plan on regeneration of coral reefs, seagrass beds and mangrove forests

to bring stable conditions to the beach through specific measures such as water quality control in lagoons, regulations to control nautical activities (sailing and motorized boats) specifically in seagrass bed areas and coral communities and plantation of coral, seagrass and mangroves.

Chapter 7

Capacity Development, Information, Education and Communication (IEC) Plan and Coastal Management System

7 Capacity Development, Information, Education and Communication (IEC) Plan and Coastal Management System

Objective of the capacity development and information, education and communication (IEC) activities in the Project is shown in the table below. The procedures of planning, activities and results as of June, 2014 are shown in the following sections.

- Capacity Development : The capacity of C/P and related agencies in coastal conservation will be developed through the Project.
- IEC : Improve awareness and understanding of stakeholders that are mainly residents and beach users through IEC activities.

7.1 Preparation of Capacity Development Plan

7.1.1 Project's Goal and Corresponding Components

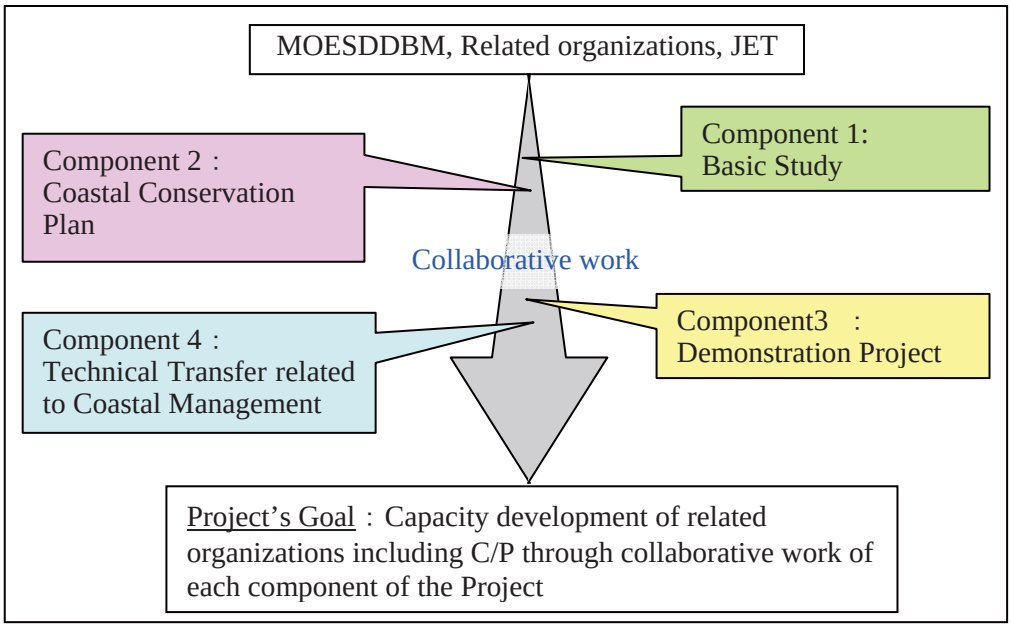
In general, procedures of coastal conservation are categorized into four stages: 1) Investigation, 2) Planning, 3) Design and Implementation, and 4) Management and maintenance. And as shown in Table 7.1.1, the components of the Project are designed to correspond to these stages, respectively.

Table 7.1.1 General Procedures of Coastal Conservation and Corresponding Components

Procedures of coastal conservation	Description	Correspondence to the Project's components
Investigation	Confirm present issues of coastal area by investigation	Component 1: Basic Study
Planning	Prepare coastal conservation plan to solve the present issues	Component 2: Coastal Conservation Plan
Design and Implementation	Design the details based on the conservation plan and conduct the implementation	Component 3: Demonstration Project
Management and maintenance	After the implementation, prepare and implement the management and maintenance plan to keep the coastal area in adequate condition.	Component 3 :Demonstration Project, and Component 4: Technical Transfer of Coastal Management

Source: JICA Expert Team

As mentioned above, the Project's goal is the capacity development of relevant agencies including C/P through collaborative work of each component of the Project. Figure 7.1.1 shows a conceptual diagram of the Project.



Source: JICA Expert Team

Figure 7.1.1 Conceptual Diagram of the Project

7.1.2 Performance Goal of Capacity Development and Target Agency

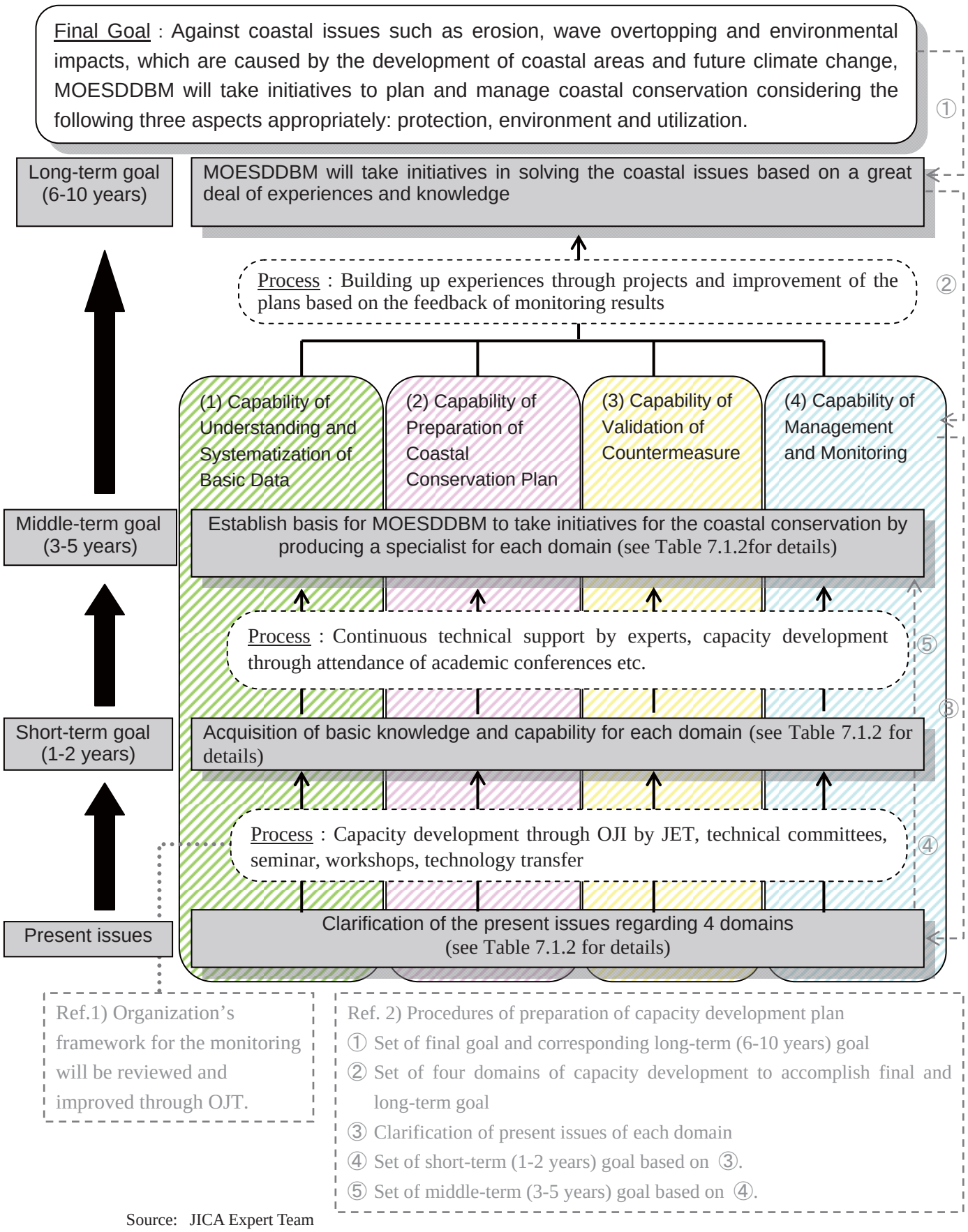
The main target of capacity development is the ICZM Div. of MOESDDBM (i.e. C/P). Their main roles are planning and management related to coastal conservation (Landell Mills, 2009) and the number of officers is limited (6 officers as of 2013). Considering these circumstances, it would not be adequate to try to develop all of their capacities (i.e. investigation, plan, design and implementation, management and maintenance) to equivalent levels. Therefore, the performance goal of capacity development and its target agencies were set with respect to each item of the components, referring to the agencies' role reviewed in Section 2.3.2.

7.1.3 Long- and Short-Term Plan of Capacity Development

In general, a successful capacity development needs a long period of time because it incorporates the following procedures: 1) acquisition of basic knowledge, 2) implementation of projects applying the knowledge, 3) capacity development through accumulation of those experiences. Considering these characteristic, the capacity development plan is prepared by the following procedures and the overview of the plan is shown in Figure 7.1.2. The role of the Project is to accomplish the short-term goal of capacity development, which mainly focuses on acquisition of basic knowledge and capacities.

<Procedures of Preparation of the Capacity Development Plan (refer to Figure 7.1.2)>

① Set final goal and corresponding long-term (6-10 years) goal
② Set of four domains of capacity development to accomplish final and long-term goal
③ Clarification of present issues for each domain (i.e. capacity assessment)
④ Set of short-term (1-2 years) goals based on ③
⑤ Set of middle-term (3-5 years) goals based on ④



Source: JICA Expert Team

Figure 7.1.2 Overview of Capacity Development Plan

Table 7.1.2 Present Issues and Corresponding Short- and Middle- Term Goals

Present Issues	Details of Short-term Goal (to be accomplished in the Project)	Details of Middle-term Goal
① Capability of Understanding and Systematization of Basic Data (corresponds to Component:1 Basic Study)		
・Long-term data that is necessary for adequate preparation of the coastal conservation plan have not been collected and organized. The data includes beach profile, wave and current, water quality and coral reef conditions. ・It is desirable to understand residents' awareness and willingness to participate in activities of the plan and needs when developing the coastal conservation plan. ・It is desirable to organize the data and information in an integrated database for use when developing the coastal conservation plan effectively.	・Understand issues to be checked at coastal areas for monitoring purpose. ・Understand overview of purpose and method of use of wave recorder and current meter. ・Understand sampling method of bottom sediment and its evaluation method with coastal profile. ・Understand survey method of habitation situation of coral reef and its evaluation. ・Understand survey method of water quality and its evaluation. ・Understand and conduct survey method of public awareness and its evaluation. ・Organize the obtained data and information above in integrated manner with commonly-used software (i.e. GIS)	・Acquire the capability to accumulate and systematize data related to the left column continuously and to identify the changes in coastal area in time series. ・Acquire the capability to identify causes of coastal disaster based on accumulated data. ・Acquire the capability to apply the database for not only post- but also pre-conservation of coastal areas.
② Capability of Preparation of Coastal Conservation Plan (corresponds to Component 2: Coastal Conservation Plan)		
・Priority areas for preparation of the coastal conservation plan are not evaluated in all coastal areas in Mauritius. Thus, priority areas to be conserved are not clear. ・In association with ① above, the coastal conservation plan in Mauritius tends to be stereotypical. This is because that the clarification process of present issues is insufficient due to lack of basic data. ・It is desirable to prepare the coastal conservation plan with an emphasis on the effects of future climate change, especially concerning the sea level rise.	・Understand and conduct the method to set priories on coastal areas for conservation using objective criterion. ・Understand appropriate procedures to prepare the coastal conservation plan: 1) identify present issues, 2) compare plans in several aspects, 3) select the most appropriate plan. ・(In addition to above), understand and conduct methods to prepare environmental-friendly and access-friendly plans in the procedures. ・Understand methods to prepare coastal the conservation plan with an emphasis on the effects of future climate change, especially with sea level rise. ・Prepare the coastal conservation plan at a case-study coast with stakeholders referring to the procedures above.	・Acquire capability to prepare coastal conservation plan with procedures described in the left column, based on experiences from the Project and referring to technical guidelines prepared in this Project.
③ Capability of Validation of Countermeasure (corresponds to Component 3: Demonstration Project and Component4 : Technical Transfer)		
・Validity of the countermeasure against coastal disasters is practically evaluated not by MOESDDBM but consultants, which could result in insufficient validation. ・In association with the above, the environmental impacts (i.e. EIA) that could be caused by the countermeasure need to be reviewed adequately. ・To make the plan contribute to direct beneficiaries such as residents and beach users, consensus building with these stakeholders is needed to be fully conducted before the implementation.	・Clearly understand the objective of the Project and reasons for selection of proposed countermeasures. ・Understand appropriate design criterion of countermeasure such as design tidal level, design wave height, dimension of countermeasures, and design weight of materials. ・Understand the evaluation items of EIA that are related to water quality, coral reef, and other natural conditions and conduct EIA evaluation. ・Understand and conduct the process of consensus building with residents and beach users with clarification of the Project's objective and its detailed design. ・Evaluate procedures and effect of countermeasures above, and list further problems.	・Acquire capability to evaluate validity of the coastal design proposed by consultants, based on experiences from the Project and referring to "Engineering guidelines". ・Acquire capability to extract evaluation items and evaluate possible environmental impacts adequately, based on experiences from the Project and referring to the "EIA guideline". ・Acquire capability to continue procedures of consensus building based on the Project experience.
④ Capability of Management and Monitoring (corresponds to Component 3: Demonstration Project and Component4 : Technical Transfer)		
・Since the monitoring survey at fixed points/ areas is not conducted, the adaptive management based on the monitoring results is not adequately conducted. ・Coastal structures that can interfere with the natural sediment transport and illegal activities have to be adequately controlled. ・A certain amount of knowledge about designing is needed to avoid inadequate design of coastal structures. ・Monitoring after implementation requires understanding and cooperation from residents and beach users. Thus, IEC activity has to be actively conducted to improve their awareness of coastal conservation.	・Understand the monitoring method of the beach profile, data arrangement and its evaluation through the Demonstration Project. ・Enhance the implementation organization for reef environment, water quality monitoring and maintenance. ・Understand the data acquisition and analysis method of waves and current data obtained by the Wave Hunters and current meters. ・Identify present issues related to the organization framework for coastal management and monitoring. And improve the problems obtained as identified above through the Demonstration Project. ・Conduct education and a public awareness campaign of coastal conservation, and implement the participatory coastal management with residents and stakeholders. ・Improve the implementation organization and regulations for the coastal management through the Demonstration Project. ・Prepare the following guidelines as a part of technical transfer cooperating with JET:① Engineering, ②Monitoring, ③Coral reef monitoring, and ④EIA. ・Set up a discussion board to exchange technological information with participants through workshops and seminars as a part of technology transfer. ・Expand one's knowledge of coastal conservation through the technology exchange in Seychelles and training in Japan.	・Acquire capability to apply adaptive management to the conservation plan by feedback of monitoring results, based on experiences from the Project and referring to "Monitoring guidelines" ・Improve public awareness of illegal activities at coastal area and check it at regular intervals. ・Conduct the participatory coastal management through continuous IEC activities, based on experiences from the Project. ・Categorize the case examples of coastal conservation in foreign countries and utilize them effectively for coastal planning in Mauritius, especially for selection of countermeasure and management method.

Source: JICA Expert Team

7.1.4 Activities related to Capacity Development

The objective of the capacity development of the Project is to accomplish short-term goals in Table 7.1.2. Capacity development activities that are conducted with C/P and relevant agencies are summarized in Table 7.1.3 and Table 7.1.4. Target agencies of the capacity development are set according to the organizations' roles in ICZM in section 2.3.2. In each item, ☑ means "it was conducted as of June 2014", and ☐ means "it will be conducted later".

Table 7.1.3 Summary of Goals, Relevant Agencies and Activities on Capacity Development (1/2)

Goals of Capacity Development (Short-term Goal)	Main Target	Summary of Activities Conducted for Capacity Development to The Relevant Agencies by JET (Items highlighted by yellow color are to be conducted by the relevant agencies and evaluated by JET(Achievement Evaluation Item)	Reference
① Capability of Understanding and Systematization of Basic Data (corresponds to Component:1 Basic Study)			
1-1. Understand issues to be checked at coastal areas for monitoring purposes.	MOESDDBM(ICZM Div.), MoLG(BA)	☑ Step1: Understand items to be checked for coastal monitoring, ☑ Step2: Understand the simplified survey method of beach profile using staff, tape measures and GPS.	Joint Field Investigation (14 beaches)
1-2. Understand overview of the intended use and method of use of the wave recorder and current meter.	MOESDDBM(ICZM Div.), MoF, MOI, MMS, MOHL	☑ Step1: Understand the importance to check characteristics of waves and currents for coastal erosion, ☑ Step2: Understand the functions of instruments (measurable item, period), ☑ Step3: Understand the installation method through actual installing at site	Installation of instruments with the relevant agency at Pte.d'Esny
1-3. Understand sampling method of bottom sediment and its evaluation method with the coastal profile.	MOESDDBM (ICZM Div.)	☑ Step1: Understand the objective of the bottom sediment study (grain size) in three beach profiles, such as 1)beach slope, 2) inside of reef, 3) edge of reef, ☑ Step2: Understand the sampling method of bottom sediment through the field survey, ☑ Step3: Understand the evaluation method for relevancy between bottom sediment samples (grain size, compositions and colors) and beach profile.	Joint Field Investigation (10 beaches)
1-4. Understand the survey method of coral reefs and its evaluation.	MoF (AFRC), MOESDDBM (ICZM Div.) MOI	☑ Step1: Understand the practical method referred to as the "spot check method as the reef damage survey, ☑ Step2: Understand the survey method through the field survey, ☑ Step3: Discuss and share the survey result with the Technical Committee and understand the current living conditions of the coral in Mauritius.	Joint Field Investigation (total 39areas), 3rd TC (Sep.2012)
1-5. Understand the survey method of water quality and its evaluation.	MoF (AFRC), MOESDDBM (NEL, ICZM Div.) CWA WMA	☑ Step1: Understand the general instruments for the water quality survey (multipurpose water quality analyzer) and its measureable items, ☑ Step2: Understand the survey method of water quality and necessity of data collections according to the water depth through the field survey, ☑ Step3: Discuss and share the survey result with the Technical Committee and understand the current water quality in Mauritius.	Joint Field Investigation (total 6areas), 3rd TC (Sep.2012)
1-6. Understand and conduct the survey method of public awareness and its evaluation.	MOESDDBM (ICZM Div., IE Div.)	☑ Step1: Understand the evaluation items (question items) for evaluation of public awareness, ☑ Step2: Conduct questionnaire survey (interview), ☑ Step3: Discuss and share the survey result with the Technical Committee and understand the tendency of public awareness for coastal management.	Joint Field Investigation (10 beaches), 5 th TC (Jan.2013), 6th TC(May 2013)
1-7. Organize the obtained data and information above in an integrated manner with commonly-used software (i.e. GIS)	MOESDDBM (ICZM Div., CC Div.)	☑ Step1: Learn how to install software and other basic operations in addition to learning the data display method, ☑ Step2: Determine the basic data and its configuration to be placed on the GIS system, ☑ Step3: Organize the required data on the GIS system ☑ Step4: Introduce the GIS system to the relevant stakeholders through Workshops.	Workshop on management and usage of database with the GIS system(June, 2014)
② Capability of Preparation of Coastal Conservation Plan (corresponds to Component 2: Coastal Conservation Plan)			
2-1. Understand and conduct a method to set priories on coastal areas for conservation using objective criterion.	MOESDDBM(ICZM Div.), MoHL, MoLG, MoF, MOI, MMS, MoTL	☑ Step1: Understand the objective indexes to select the prior coastal area which should be conserved, such as 1) natural/geological characteristics, 2) environmental characteristics, 3) shore transformation properties and 4) shore use properties, ☑ Step2: Prioritize the target beach for the coastal conservation plan among public beaches all over Mauritius using the indexes mentioned above. For example; all 58 beaches (Total number of beaches in Mauritius)-→ 20 beaches (for basic study) -→ 12 beaches (the target for the coastal conversation plan)	5 th TC (Jan.2013), 6th TC(May 2013)
2-2. Understand appropriate procedures to prepare the coastal conservation plan: 1) identify present issues, 2) compare plans in several aspects, 3) select most appropriate plan.	MOESDDBM(ICZM Div.), MoHL, MoLG, MoF, MOI, MMS, MoTL	☑ Step1: Grasp the current condition (such as 1) natural/geological characteristics, 2) environmental characteristics, 3) shore transformation properties and 4) shore use properties), and list up problems for preparing the coastal conservation plan (12 beaches), ☑ Step2: Prepare the practical countermeasures (3 cases) to solve the problems mentioned above. And clarify the merits & demerits for each countermeasure. ☑ Step3: Confirm the adequacy of the plan with the relevant agencies, ☑ Step4: Finalize the plan with the relevant agencies with an emphasis on feasibility in the future.	5 th TC (Jan.2013), 6th TC(May 2013), Working Session (Jun. 2013, Mar. 2014), Workshop (Jun. 2013,

Goals of Capacity Development (Short-term Goal)	Main Target	Summary of Activities Conducted for Capacity Development to The Relevant Agencies by JET (Items highlighted by yellow color are to be conducted by the relevant agencies and evaluated by JET(Achievement Evaluation Item)	Reference
2-3. (In addition to above), understand and conduct methods to prepare environmental-friendly and access-friendly plans in the procedures.	MOESDDBM(ICZM Div.), MoHL, MoLG, MoF, MOI, MMS, MoTL	☑ Step1: Grasp the current beach conditions and list the problems of land use control from the following viewpoints: 1) Type of existing coastal protection facilities, 2) existing facilities/structures in the set-back area, ☑ Step2: Grasp the current beach conditions and list the problems of beach usage at every beach from the following viewpoints: 1) beach cleaning, 2) vehicle approach, 3) drainage and waste water facility, 4) marine sports and fishery, 5) natural vegetation, ☑ Step3: Grasp the current reef conditions and list the problem of reef environments from the following viewpoints: 1) growth of algae, 2) water transparency, 3) silt contents, 4) eutrophication, ☑ Step4: Review the current land use and environmental feed-back regarding the coastal conservation plan with the relevant agencies.	and Oct. 2014)
2-4. Understand methods to prepare the coastal conservation plan with emphasis on the future effects of climate change, especially regarding sea level rise.	MOESDDBM(ICZM Div.), MoHL, MoLG, MoF, MOI, MMS, MoTL	☑ Step1: Review the appropriate buffer zone(set-back line) considering the past beach erosion and future sea level rise, ☑ Step2: Compare the above set-back line with the existing one, and prepare regulation revisions if necessary.	
2-5. Prepare the coastal conservation plan at the case-study coast with the stakeholders referring to the procedures above.	MOESDDBM(ICZM Div.), MoHL, MoLG, MoF, MOI, MMS, MoTL	☐ Step1: Select one beach for the case study (not including the beaches which have already been studied above), and determine the coastal conservation plan according to the procedure aforementioned, ☐ Step2: Finalize the above plan through discussions at the Technical Committee with the relevant agencies.	

＊DC: District Council, BA: Beach Authority
Source: JICA Expert Team

Table 7.1.4 Summary of Goals, Relevant Agencies and Activities on Capacity Development (2/2)

Goals of Capacity Development (Short-term Goal)	Main Target	Summary of Activities Conducted for Capacity Development to The Relevant Agencies by JET (Items highlighted by yellow color is to be conducted by the relevant agencies and evaluated by JET(Achievement Evaluation Item)	Reference
③ Capability of Validation & Adjustment of Countermeasures (corresponds to Component 3: Demonstration Project and Component4 : Physical measures, non-physical measures)			
3-1.Clearly understand the objective of the Project and reasons for selection of proposed countermeasures.	MOESDDBM (ICZM Div.)	<Physical Measures(Grand Sable)> ☑ Step1: Select Demonstration Project complying with the technical and political aspects of Mauritius (12 beaches -→ 2 beaches), ☑ Step2: Clearly understand the objective of the Demonstration Project (i.e. to examine the effectiveness of new countermeasures for wave overtopping prevention) and its characteristics (i.e. not a development but an experimental purpose), <Non-physical Measures (Pte. d'Esny)> ☑ Step1: Select Demonstration Project complying with the technical and political aspects of Mauritius (12 beaches -→ 2 beaches), ☑ Step2: Understand clearly the objective of the Demonstration Project and the characteristics (i.e. project purpose and countermeasures considering the continuity of the coast drift sand)	7th TC (Aug. 2013), 8th TC(Sep. 2013), MOESDDBM Internal Meeting
3-2.Understand the appropriate design criterion of countermeasures such as design tidal level, design wave height, dimension of countermeasures, and design weight of materials.	MOESDDBM (ICZM Div.)	<Physical Measures(Grand Sable)> ☑ Step1: Understand the setting process of external forces required for the design of wave overtopping prevention structures (i.e. 1) design tidal level, 2) design wave height, 3) wave run-up height), and the design criterion (i.e. 1) crown height, 2) crown width, 3) slope gradient, 4) grain size), <Non-physical Measures (Pte. d'Esny)> ☑ Step1: Understand the design method of anti- drift sand facilities and its criterion (i.e. 1) facility interval, 2) facility length, 3) facility height)	<Grand sable> 7th TC (Aug. 2013), 8th TC(Sep. 2013) <Pte. d'Esny> 10th TC(April, 2014), 11th TC(Oct. 2014)
3-3.Understand the evaluation items of the EIA that are related to water quality, coral reef, and other natural conditions and conduct an EIA evaluation.	MOESDDBM (ICZM Div., EIA Div.)	<Physical Measures(Grand Sable)> ☑ Step1: Understand the evaluation items of the EIA for implementation of the coastal conservation measures (artificial stone nourishment), ☑ Step2: Evaluate the validity of countermeasures from the aspect of the environmental impact using the above evaluation items, <Non-physical Measures (Pte. d'Esny)> ☑ Step1: Understand the evaluation items of the EIA for implementation of the coastal conservation measures (removal of existing jetty, sand bypass, etc.), ☑ Step2: Evaluate the validity of countermeasures from the aspect of the environmental impact using the above evaluation items.	8th TC(Sep. 2013)
3-4.Understand and conduct the process of consensus building with residents and beach users and clarify the Project's objective and its detailed design.	MOESDDBM(ICZM Div.), MoLG(DC)	<Physical Measures(Grand Sable)> ☑ Step1:Grasp the residents awareness and requests/demands regarding coastal conservation (conduct interview survey), ☑ Step2: Confirm the basic opinions of residents towards countermeasures through the resident's representative meeting, ☑ Step3: Obtain the final consensus of residents throughout the entire residents meeting, <Non-physical Measures (Pte. d'Esny)> ☑ Step1: Grasp the land owner's awareness and demands for coastal conservation (conduct interview survey), ☑ Step2: Confirm the basic opinions of land owners towards countermeasures through the individual meeting (incl. field hearing), ☑ Step3: Obtain the final consensus of land owners throughout the entire land owners meeting.	<Grand Sable> -Interview survey (Jun. 2013), -Resident's representative meeting (Aug.2013), -Whole residents meeting (Sep.2013), <Pte.d'Esny> -Individual meeting, interview survey (Apr. Jun., 2014), -Field hearing (Jun. 2014)
3-5. Evaluate procedures and the effect of countermeasures above, and list up further problems.	MOESDDBM (ICZM Div.)	☑ Step1: Summarize the procedure series, effects of countermeasures and further problems considering the aforementioned physical measures and non-physical measures (in 5 sheets of A4 sized paper), ☐ Step2: Make presentation, explanation of the above summary externally (i.e. At an International conference, etc.).	Note: C/P joined as cowriter of technical book completed in Oct 2014
④ Capability of Management and Monitoring (corresponds to Component 3: Demonstration Project and Component4 : Technology Transfer of Coastal Management)			
4-1.Understand the monitoring method of the beach profile, data arrangement and its evaluation through the Demonstration Project.	MOESDDBM(ICZM Div., LEU), MoHL, MoLG(BA), MoF, MoI	☑ Step1: Conduct the beach profile survey with auto-level regularly at the target beach for monitoring, ☑ Step2: Accumulate and sort out the survey data in the required format, ☑ Step3: Grasp the current beach profile and its change based on the survey data, and evaluate the existing problem, ☑ Step4: Prepare the appropriate management plan according to the existing problem of coastal erosion (if necessary).	Joint Field Investigation (Targeted 7 beaches)

Goals of Capacity Development (Short-term Goal)	Main Target	Summary of Activities Conducted for Capacity Development to The Relevant Agencies by JET (Items highlighted by yellow color is to be conducted by the relevant agencies and evaluated by JET(Achievement Evaluation Item)	Reference
4-2. Enhance the implementation organization for the reef environment, water quality monitoring and maintenance.	MOESDDBM(ICZM Div., LEU), MoF, MOI	☑ Step1: Share the monitoring data of reef environments and water quality with the existing monitoring agencies (MoF, MOI). ☑ Step2: Conduct a case-study for coral reef conservation at Albion, ☑ Step3: Determine the framework of the coral reef conservation plan through the Technical committee (MOESDDBM, MOI, AFRC, university). ☑ Step4: Finalize the coral reef conservation and management plan through the above committee. ☐ Step5: Consider the application of international standards for water quality/threshold value regarding coral reef.	-
4-3.Understand the data acquisition and analysis method of wave and current data obtained by the Wave Hunters and current meters.	MOI, MMS, MOESDDBM (ICZM Div.)	☑ Step1: Understand the basic contents of the wave and current measurement methods and the related instruments (Wave Hunter, Electromagnetic Flow Meter). ☑ Step2: Obtain basic operation skills through the workshop for setting the measurement instruments. ☑ Step3: Understand the series of works for setting and removal of instruments through field activities. ☑ Step4: Conduct the series of works at observation site. 1) removal 2) data collection, 3) setting-up instruments, 4) replacing instruments. ☑ Step5: Prepare time series graphs using Excel software (preliminary treatment) based on the collected data. ☑ Step6: Understand the feedback method of collected data to the coastal conservation plan in the target area.	- Explanatory meeting for measurement instruments (Jun.2013), - Conducting workshop for setting instruments (Oct.2013), - Setting up instruments at site by relevant agency (Apr.2014-), - Explanatory meeting for data analyzing method and feedback to the coastal conservation plan (Jun.2014-)
4-4.Identify present issues related to the organizational framework for coastal management and monitoring. And improve the problems obtained as identified above through the Demonstration Project.	MOESDDBM(ICZM Div.), MoHL, MoLG(BA), MoF, MOI	☑ Step1: Identify present problems related to staff employment and cooperation of each agency observing the existing monitoring organization. ☑ Step2: Improve the organization and system for monitoring based on the problems mentioned above (if necessary).	-
4-5.Conduct education and public awareness campaigns for coastal conservation, and implement participatory coastal management with residents and stakeholders.	MOESDDBM(ICZM Div.), MoLG(DC)	<Physical Measures (Grand Sable)> ☑ Step1: Conduct beach cleaning with the residents as the first step of the participatory coastal management. ☑ Step2: Assist the establishment of the resident's monitoring team, and build up the system to take photos of the coastal situation regularly at certain points. ☑ Step3: Discuss the effect of countermeasures based on the monitoring results from the view point of effect, influence and improvement through the resident's representative meeting. And support the improvement of the resident's awareness and understanding for countermeasures. ☑ Step4: Conduct the residents meeting (if necessary). Finalize the appropriate management plan based on the points to be improved, and implement it. ☑ Step5: Promote the following things to enhance the coastal management organization: - Establish self-management organization by residents and land owners. - Certify the target beach as Pubic Beach by government (MoHL, MoLG) <Non-physical Measures (Pte. d'Esny)> ☑ Step1: Improve the residents' awareness and their willingness to participate in coastal conservation through discussions in several stakeholder meetings with the residents.	<Grand Sable> -Beach cleaning (Oct.2013), - Formulation of resident's monitoring team and conducting monitoring (Dec. 2013-), - Confirmation meeting for maintenance & operation (May 2014), - Confirmation of maintenance & operation activity (Jun. 2014-) <Pte. d'Esny> General meeting (3 times: Mar, May, Oct, 2015) Individual meeting (2 times: June, Oct., 2015)
4-6.Improve the implementation organization and regulations for coastal management through the Demonstration Project.	MoLG (BA,DC), MOESDDBM (ICZM Div.)	<Physical Measures (Grand Sable)> ☑ Step1: Improve public awareness of coastal management through the above participatory coastal activities. ☑ Step2: Raise awareness about illegal activities at coastal areas (illegal waste dumping, gravel mining, private building construction) through Work Shops and so on. ☑ Step3: Strengthen the control on illegal activities at coastal areas cooperating with the MoLG. <Non-physical Measures (Pte. d'Esny)> ☑ Confirm actual conditions of coastal land management and land contract. ☑ Based on the above, suggest improvements for land management and land contracting.	<Grand Sable> Explanatory meeting with the residents about illegal activities (Apr., May, Oct 2014) <Pte. d'Esny> Discussion with MoHL on land management and land contract (Oct.,2103, June, Oct, 2014)
4-7.Prepare the following guidelines as a part of technical transfer in cooperation with JET: ① Engineering, ② Monitoring, ③Coral reef monitoring, and ④EIA.	MOESDDBM(ICZM Div., EIA Div.), MoHL, MoLG(BA),	☑ Step1: Discuss with the relevant agencies in order to prepare a working-level guideline, and finalize the contents of the guideline. ☑ Step2: Prepare each Guideline. During the preparatory process, review the coastal conservation plan and relevant parts	Workshop for contents of Guideline (Jun. 2014)

Goals of Capacity Development (Short-term Goal)	Main Target	Summary of Activities Conducted for Capacity Development to The Relevant Agencies by JET (Items highlighted by yellow color is to be conducted by the relevant agencies and evaluated by JET(Achievement Evaluation Item)	Reference
	MoF, MOI	of the Demonstration Project, and prepare it reconfirming the technical contents. ☐ Step3: Verify the adequacy of the design referring to guidelines based on the existing structure (i.e. wet-stone masonry at Grand Baie) in Mauritius.	
4-8.Set up a discussion board to exchange technological information with participants through workshops and seminars as a part of technology transfer.	MOESDDBM(ICZM Div.), MoHL, MoLG, MoF, MOI, MMS, MoTL, etc.	☑ Step1: Promote awareness and understanding of coastal conservation regarding the results of the coastal conservation plan through Work Shops for the relevant government agencies. ☑ Step2: Conduct workshops and seminars for the relevant government agencies and international organizations (IOC, UNDP, etc.) regarding the results of the Demonstration Project, and disseminate information about it for exchanging opinions.	- Conducting workshops and seminars (Jun. 2013, Sep. 2014), - Putting up posters regarding results of physical countermeasures (at Grand Sable) on Environmental Day in Mauritius (May 2014)
4-9.Expand knowledge of coastal conservation through the technology exchange in Seychelles and training in Japan.	MOESDDBM(ICZM Div., EIA Div., PPC Div., LEU), MOI, MPI	☑ Step1: Expand the knowledge of coastal conservation and coastal management at reef zones through the technology exchange in Seychelles which has a similar natural environment. ☑ Step2: Expand the knowledge of coastal conservation and coastal management based on the case study, countermeasures for coastal conservation facilities and participatory coastal management at reef zones through the technology exchange in Japan.	- Technology exchange in Seychelles (Jun.2013), - Training in Japan (Dec.2013)

＊DC: District Council, BA: Beach Authority
Source: JICA Expert Team

Photos below show the activities for capacity development with the relevant agencies during the Basic Study (Component 1). Details of other activities required by other components are described in each related section.

(Item 1-1) Field survey at coasts

(Item 1-2) Installation of wave current meter

(Item 1-5) Water Sampling

(Item 1-5)Water Quality Check by Multipurpose Water Quality Analyzer

(Item 1-6) Execution of joint interview survey

(Item 1-7) Guidance for basic operation of Arc GIS

Source: JCIA Expert Team

Figure 7.1.3 Activity for Capacity Development with the Relevant Agencies during the Basic Study
(Item No. is corresponding to Table 6.1.3 & 6.1.4)

7.2 Information, Education and Communication (IEC)

7.2.1 IEC in Beach Conservation Project

a. General Definition of IEC

In general, IEC is a process of disseminating information to the user of this particular service. IEC activity means that service providers conduct a variety of activities for disseminating information to give an opportunity to gain a better understanding and lead to a behavior change for the service users. IEC can be categorized as shown below.

Table 7.2.1 General Definition of IEC

	Information	Education	Communication
Definition	Information and/or data in itself to be provided to an individual or public	A gradual process of learning through which a person gains knowledge and understanding of a project	A two way process of giving information or sharing ideas between two or more people

Source: JICA Expert Team

b. IEC in the Beach Conservation Project

In this study, IEC activities are categorized as shown in Table 7.2.2, considering characteristics and actual conditions of the coastal conservation plan. The term of "communication" in Table 7.2.2 is considered as "consensus building for the coastal conservation plan", which is one of the main objectives of IEC activities. The public relations, which is usually referred to as PR, is generally included in the IEC, however, the term is categorized separately from the IEC for the purpose of clarifying the objective, which is aimed to spread the activities' effects to other organizations and nationwide.

Table 7.2.2 IEC in Beach Conservation Project

Information	Education	Communication	Public Relations
・ General information about coastal conservation and disaster to be provided ・ Considered the first stage of IEC activities	・ A process of learning through which a person gains knowledge and understanding of coastal conservation and disaster and protection ・ Considered the second stage of IEC activities	・ Consensus building for the proposed coastal conservation plan. ・ To gain Consensus building through Communication ・ Considered the third stage of IEC activities	・ To spread the project effect by public relations of the consensus building process as well as the output to organizations and related countries ・ Considered the fourth stage of IEC activities

Source: JICA Expert Team

7.2.2 Improvement Plan of IEC Activities Based on Present Issues

To clarify the present issues relating to IEC activities, an interview was conducted with the Information and Education Division, which has been in charge of IEC activities in MOESDDBM. The extracted problems from the interview survey and the proposed countermeasures are briefly listed in Table 7.2.3.

According to the interviews, the division has conducted IEC activities such as educational activities through TV, radio, and newspaper outlets and so on. On the other hand, they recognized that there were few IEC activities focused on coastal disaster protection and few cases to confirm accomplishment (i.e. how it worked practically) of their activities. Thus, they have a vision to improve the “feedback or evaluation of one’s understanding” to make IEC activities more suitable to one’s needs. From this point of view, the JICA expert team also shares the same vision as they have in terms of the improvement of the activities.

Honest communication by stakeholders is needed to solve the abovementioned problems. Therefore, stakeholder meetings will be held in this project as a place of mutual communication about the coastal conservation plan. Stakeholder meetings are planned to be held for both physical and non- physical measures in the Demonstration Project that are necessary to gain consensus amongst stakeholders.

Table 7.2.3 Existing Problems of IEC and corresponding Countermeasures

Main IEC activities in this study / Existing problems extracted by the interview (Details of activities)	Hearings with past coastal disasters such as erosion and wave overtopping.	Hearings with possible impacts on coastal zone s by climate change.	Hearings with desirable adaptations against coastal disasters.	Interactive survey with residents who live at eroded coastal areas	Discussion with stakeholders about beach the conservation project at each district.	Stakeholder meeting with the residents described at left column	Improvement of beach conservation plan based on the stakeholders' opinion.	To spread the activities' effects to other organizations and nationwide.	Public relations of the process and results of IEC activities
1. The implicit knowledge of residents about past coastal disasters is not yet organized as available formal knowledge.	○		○		○				
2. Educational activities to residents about past coastal disasters are not yet effectively performed.		○	○		○				
3. Opinions by stakeholders are not fully considered into coastal conservation plans.			○		○		○		
4. Coastal management including awareness of illegal activities and daily maintenance is not fully conducted by stakeholders.					○		○	○	
5. Confirmation of people's understandings about given information by IEC activities is not performed.					○				
6. Sufficient cooperation with other organizations and countries is needed to help the Project gain a ripple effect.								○	

Source: JICA Expert Team

7.2.3 Overview of the IEC Activity Plan

According to the definition of the IEC and existing problems and corresponding countermeasures, the IEC activity plan in this study is presented in Table 7.2.4. IEC activities conducted in the Project as of Oct., 2013 are shown in related Chapters in the Table. It is proposed that MOESDDBM and relative stakeholders shall implement these IEC activities by referring to the practice examples conducted in the Project.

Table 7.2.4 IEC Activity Plan

	Information	Education	Communication	Public Relations
IEC definition in this study	・ General information about coastal protection and disaster to be provided ・ Considered the first stage of IEC activities	・ A process of learning through which a person gains knowledge and understanding of coastal disaster and protection ・ Interactive survey is applied to aggregate information from person's experience ・ Considered the second stage of IEC activities	・ Consensus building for the proposed coastal conservation plan ・ To gain Consensus building through Communication ・ Considered the third stage of IEC activities	・ To spread the project effect by public relations of the consensus building process as well as the output to organizations and related countries ・ Considered the fourth stage of IEC activities
Target	・ Residents who live around areas with erosion and/or wave overtopping problems ・ 10 coastal areas in Mauritius		・ Residents(same as left column) ・ Two coastal areas: One for Physical measures area and one for Non-Physical measures area in the Demonstration Project	・ Citizens of Mauritius ・ Organizations such as UNDP, IOC
Method of activities	・ Interactive survey for the residents / beach users including tourists		・ Stakeholder meeting at each district	・ Public relations by TV, radio, newspaper outlets and so on.
Details	Ch. 2.7 Public Awareness		Ch.8.3.5 Consensus Building	Ch. 8.3.9 Participatory coastal management and IEC
Implementation body	MOESDDBM、JET To implement effective technical transfer, MOESDDBM mainly conduct activities with instruction by JET.			MOESDDBM, JET and related organizations

Source: JICA Expert Team

7.3 Proposed Coastal Management System, Organization Framework and Legislation

Based on the capacity development through the Project, coastal management and the organizational framework are proposed as follows.

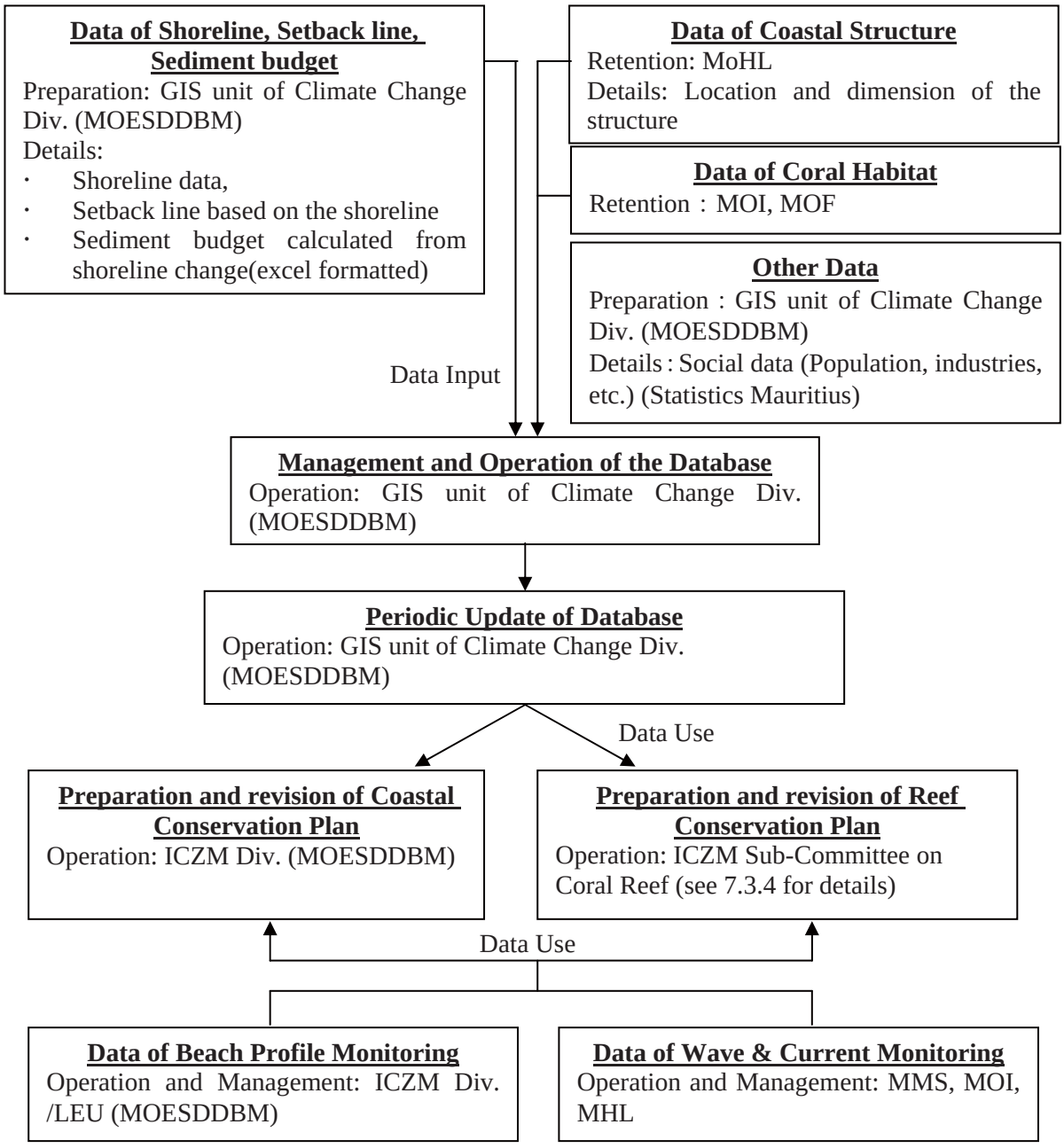
<Proposed coastal management and organizational framework>

- Management system of coastal environment database
- Implementation system of beach profile monitoring
- Implementation system of wave and current monitoring
- Implementation system for reef environment conservation
- Implementation system for participatory coastal management
- Coastal management system with beach reprofiling
- Improvement on legislation of the contract and usage of leased coastal areas
- Management system of sand reuse.

7.3.1 Management System of Coastal Environment Database

Regarding the coastal environment database organized in the Project, the proposed management system is presented in the figure below. The objective of database management is to accumulate and update social and scientific data that would be necessary to prepare or revise the coastal conservation and reef environmental plans.

The GIS unit of the Climate Change Div. in MOESDDBM shall manage GIS related data that includes shoreline data as well as other data from other ministries. The monitoring data of the beach profile and wave & current data shall be managed by its implementation bodies as they require technical knowledge.



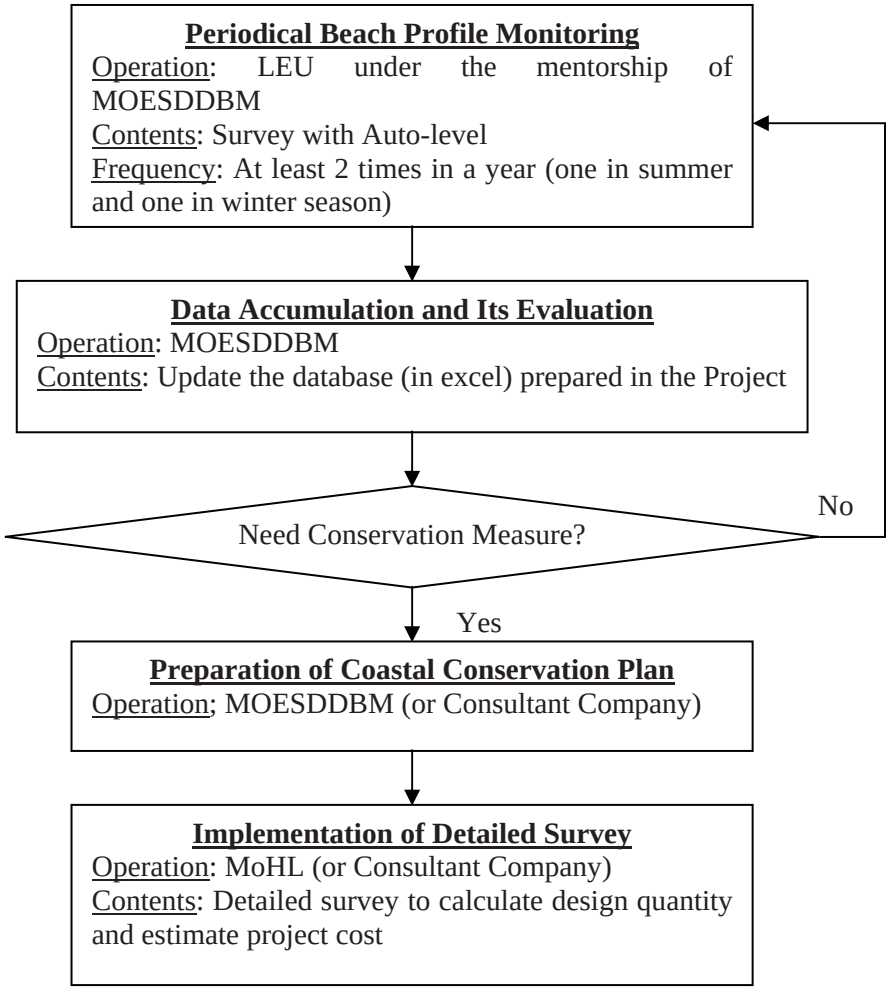
Source: JICA Expert Team

Figure 7.3.1 Proposed Management and Operation System of Coastal Environment Database

7.3.2 Implementation System of Beach Profile Monitoring

The objective of beach profile monitoring is to confirm periodic changes and to apply it to the preparation of adaptive conservation measures. In Mauritius, dominant wind and wave directions change in the summer and winter seasons. Therefore, we propose monitoring more than two times (i.e. one in summer and the other in winter season) a year.

Though the shortage of manpower for monitoring was anticipated in the beginning, now it works well by getting support staff from LEU. Though the monitoring is now conducted every three months for every target beach. Two times in a year as mentioned above would be sufficient for monitoring frequency if the change of beach profile is considered small based on the monitoring results obtained from the Project. Again, since the purpose of monitoring is to check the changes of the beach profile, high accuracy instruments such as the total station will not necessarily be needed. The more important thing is to continue this kind of monitoring for a long period to accumulate the data. If concrete countermeasures are considered necessary from the monitoring results, then there would be a need for high accuracy instruments to calculate design quantity and project cost, as described in the Figure below.

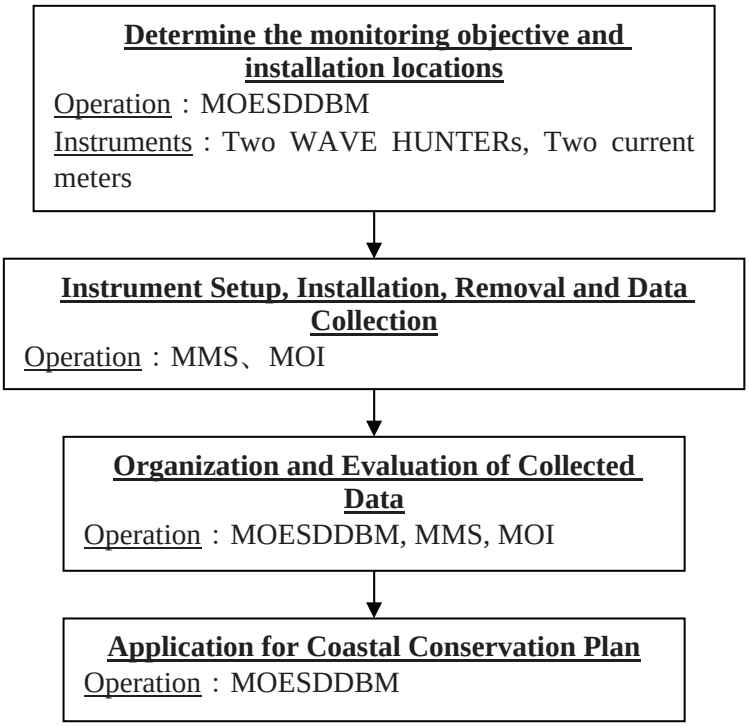


Source: JICA Expert Team

Figure 7.3.2 Proposed Implementation System of Beach Profile Monitoring

7.3.3 Implementation System of Wave and Current Monitoring

Two WAVE HUNTERs and two current meters were handed over to MMS and MOI and they shall implement the monitoring after the Project. After collecting data, MOESDDBM shall evaluate them and apply it to prepare the coastal conservation plan.



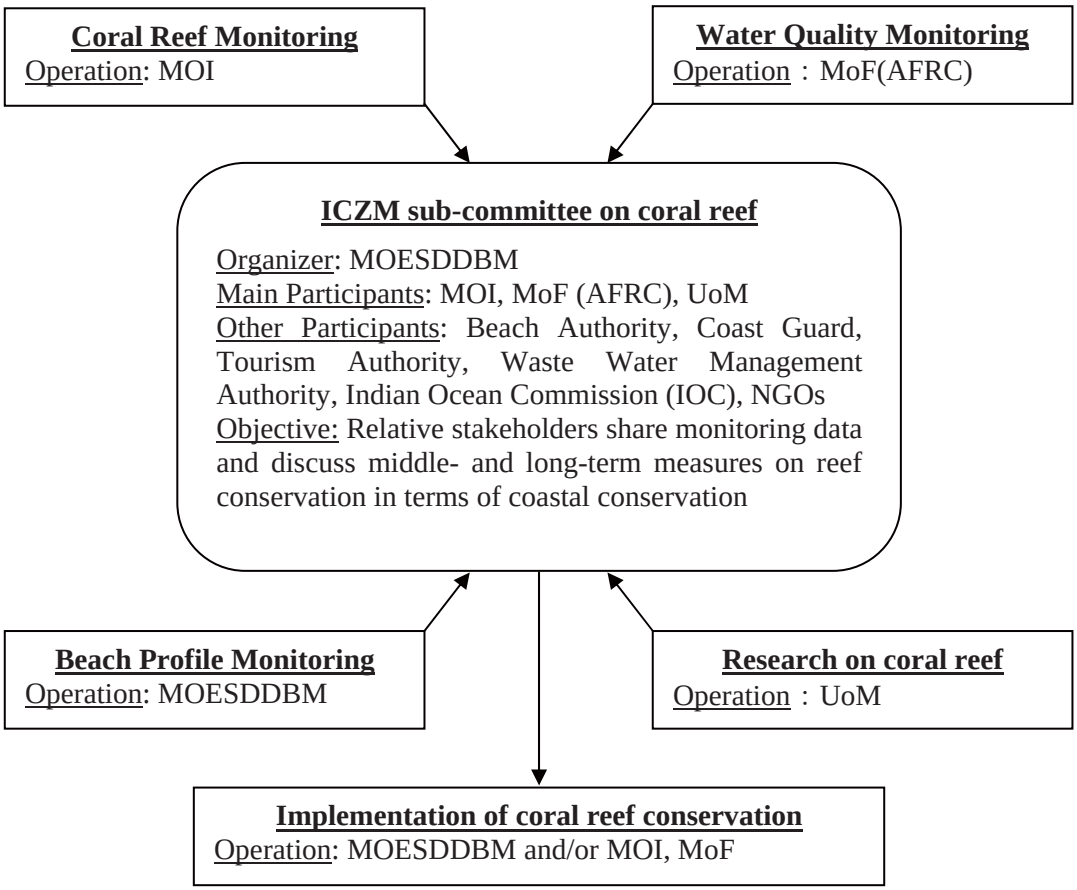
Source: JICA Expert Team

Figure 7.3.3 Proposed Implementation System of Wave and Current Monitoring

7.3.4 Implementation System for Reef Environment Conservation

Reef and water quality monitoring have been conducted by MOI and MoF (AFRC) respectively and they have expertise and know-how in these areas. Thus, it is important for MOESDDBM to cooperate with them to prepare the reef environment conservation plan. We propose that the existing "Sub Committee on Coral Reef" under the ICZM Committee prepare the reef environment conservation plan from the point of coastal conservation (i.e. not only for reef conservation but also for coastal conservation).

The new standard value of water quality for coral reefs is proposed in the Project (see Ch.6 for details). It is expected the proposed committee will apply these values as a new standard.

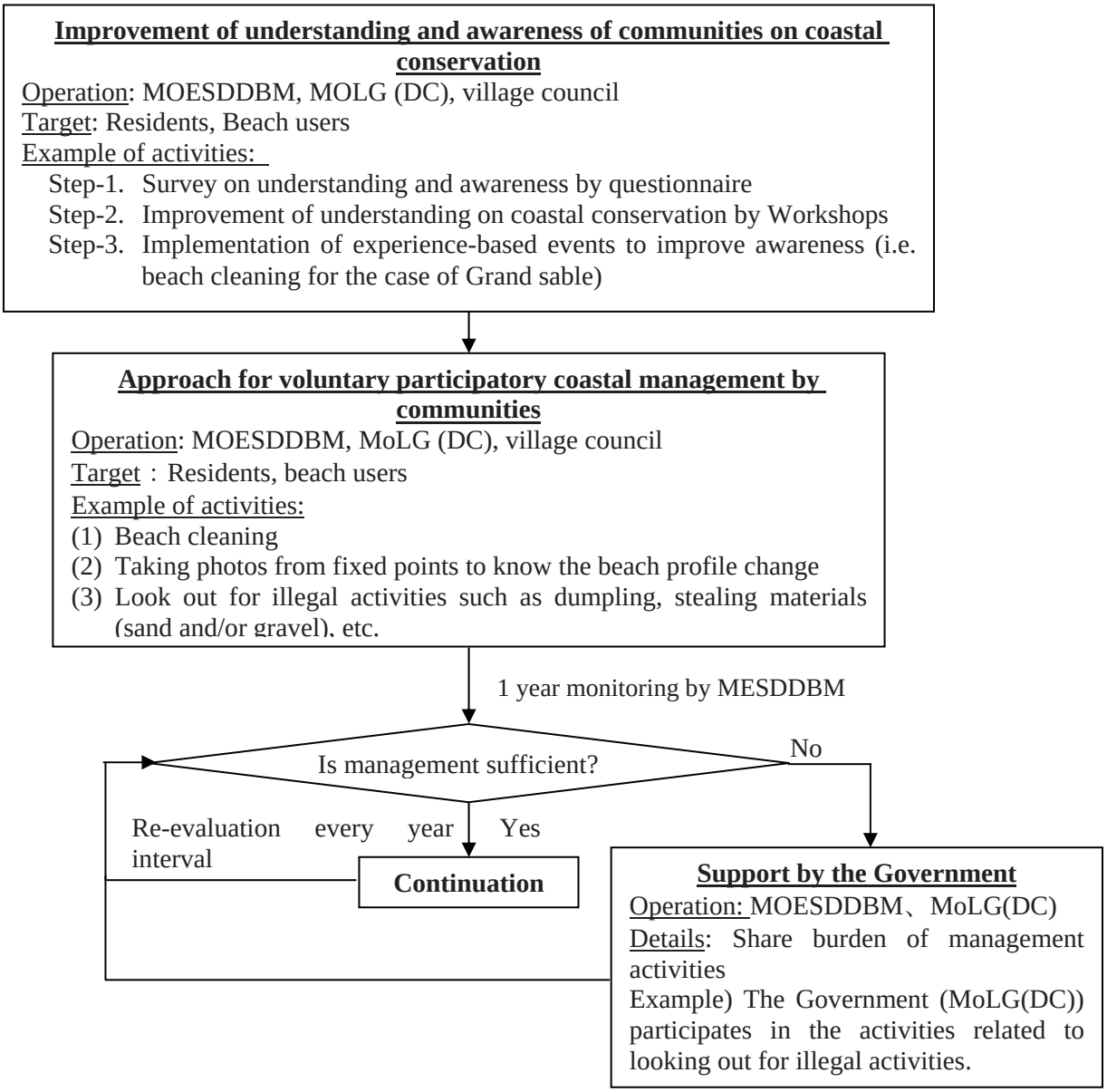


Source: JICA Expert Team

Figure 7.3.4 Proposed Implementation System of Reef Environment Conservation

7.3.5 Implementation System for Participatory Coastal Management

Coastal areas in Mauritius are classified as Public Beaches, Leased Areas, Vested Areas and Uncommitted Areas (see details in Ch.2). Among these, public beaches are managed by the beach authority, However, the leased area is managed only by its private owner and no specific management body exists for uncommitted areas. In reality, with limited manpower it is difficult for the government to manage those additional coastal areas. Thus, it is strongly recommended to make communities get involved in the coastal management issues and raise their awareness to the fact that the coastal environment belongs to them (sense of ownership). So they need to maintain the coast in a clean state for their own benefit. In this Project, participatory coastal management by communities had been implemented in Grand Sable, which is an uncommitted area. It is important to apply these approaches of participatory coastal management to other coastal areas.



Source: JICA Expert Team

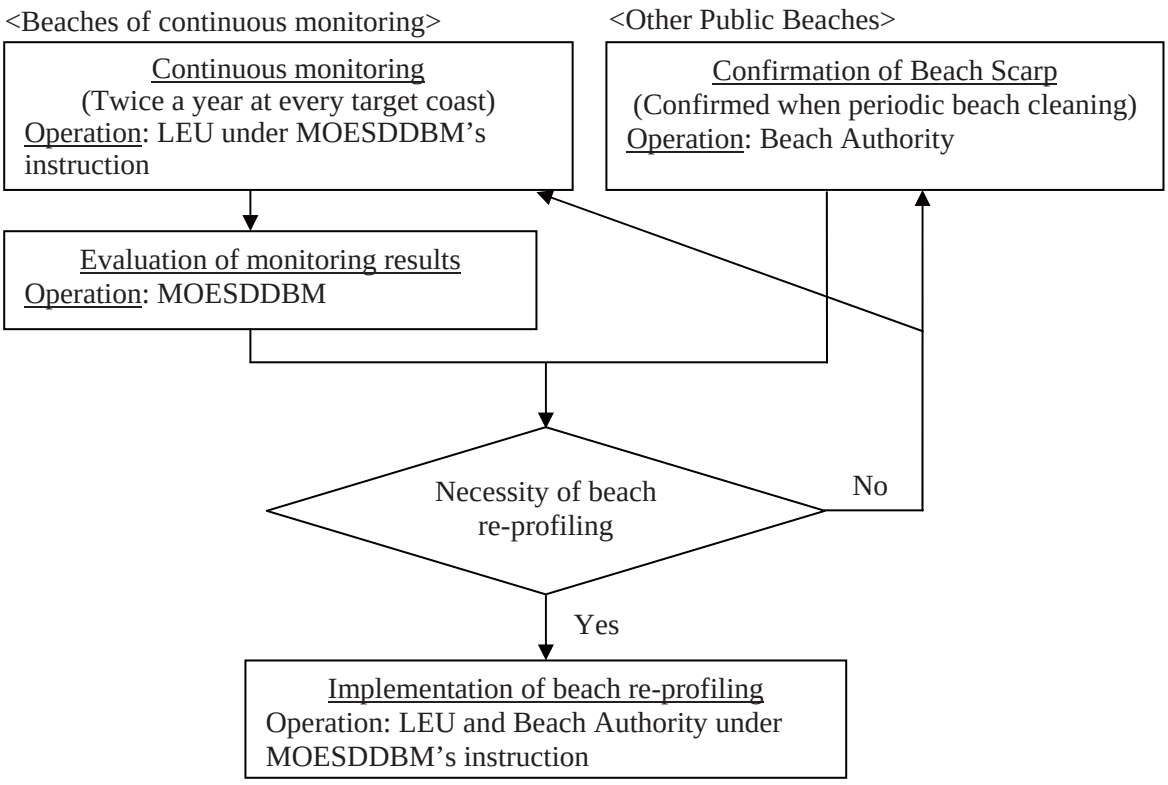
Figure 7.3.5 Proposed Implementation System of Participatory Coastal Management

7.3.6 Coastal Management System with Beach Re-profiling

Beach scarp is formed as a result of beach erosion mainly caused by high waves. The normal beach profile might be regained through the action of other high waves or the erosion may continue to advance. In the latter case, the formed beach scarp can become an obstacle for beach access as well its scenery. Thus countermeasures have to be implemented as a priority for beach scarps, especially in popular tourist beaches and public beaches. Beach reprofiling is proposed and applied as a countermeasure against beach scarps in this Project. We propose that beach re-profiling shall be applied to popular tourist coasts and public beaches including continuous monitoring of beaches in this Project.

For beaches with continuous monitoring, the necessity of beach re-profiling shall be evaluated based on the monitoring results of the beach profile. For other public beaches, it is important to first collect information about beach conditions from the Beach Authority who conducts periodic beach cleaning in public beaches. And the necessity of measures shall be evaluated based on their information.

Some space or a buffer zone behind the beach is required for the implementation of beach reprofiling. If there is no space behind, beach re-profiling has to be conducted in combination with beach nourishment in front of the beach.



Source: JICA Expert Team

Figure 7.3.6 Proposed Coastal Management System with Beach Re-profiling

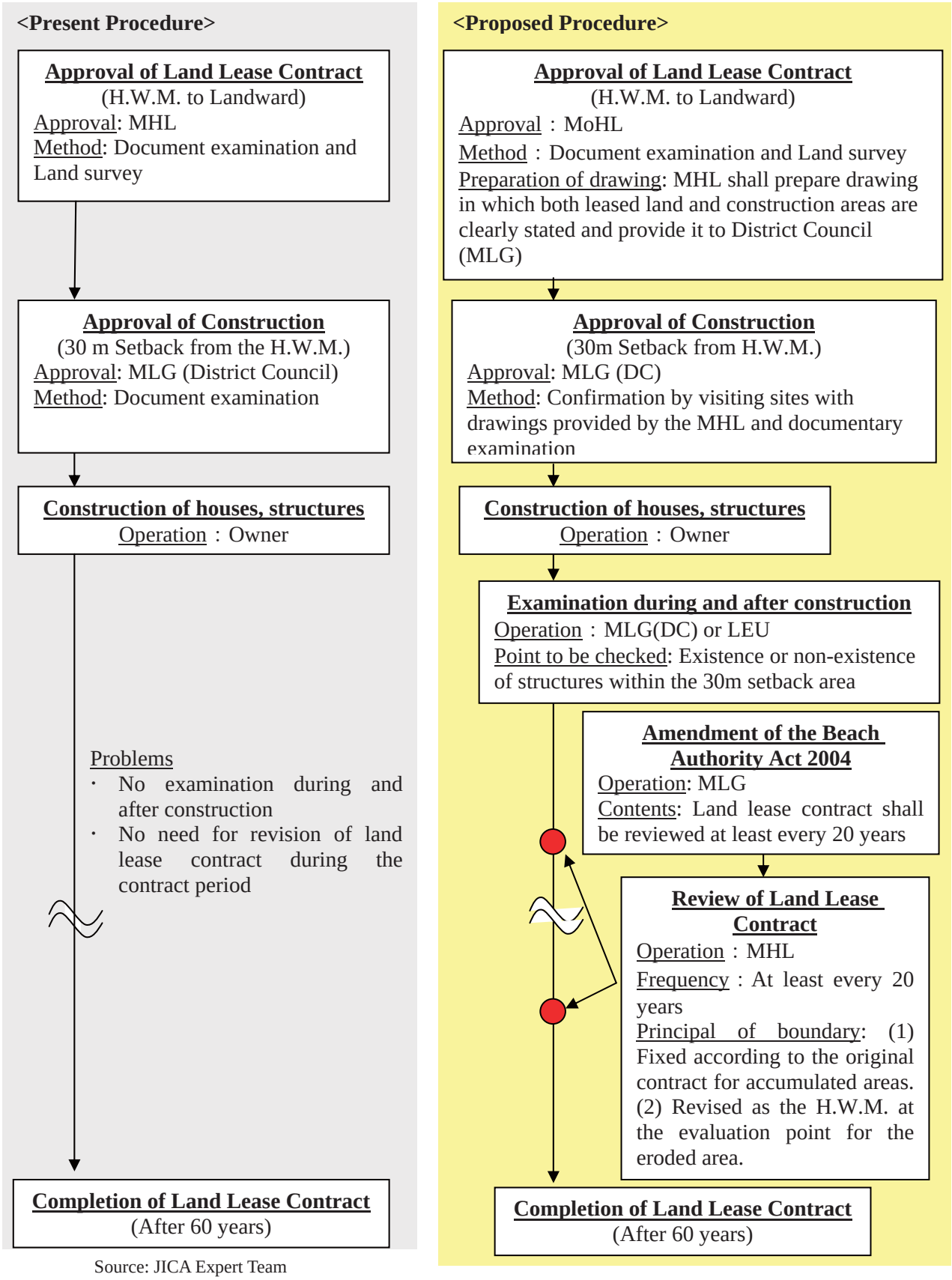
7.3.7 Improvement of Legislation on Contracting and Usage of Leased Coastal Areas

There are a lot of structures, such as house walls, seawalls, and groynes near the shoreline in Mauritius and they interfere with sediment transport along the shore and cause beach erosion at nearby areas. One typical case is Pte. d'Esny (non-physical demonstration project site). The Table below shows the actual conditions and issues of the lease contract and land usage in the coastal area that became apparent through the Project. In addition, proposal for revision of the lease contracting procedures is presented in the Table below and the following page.

Table 7.3.1 Actual Conditions and Issues on the Lease Contract and Proposal for Revision

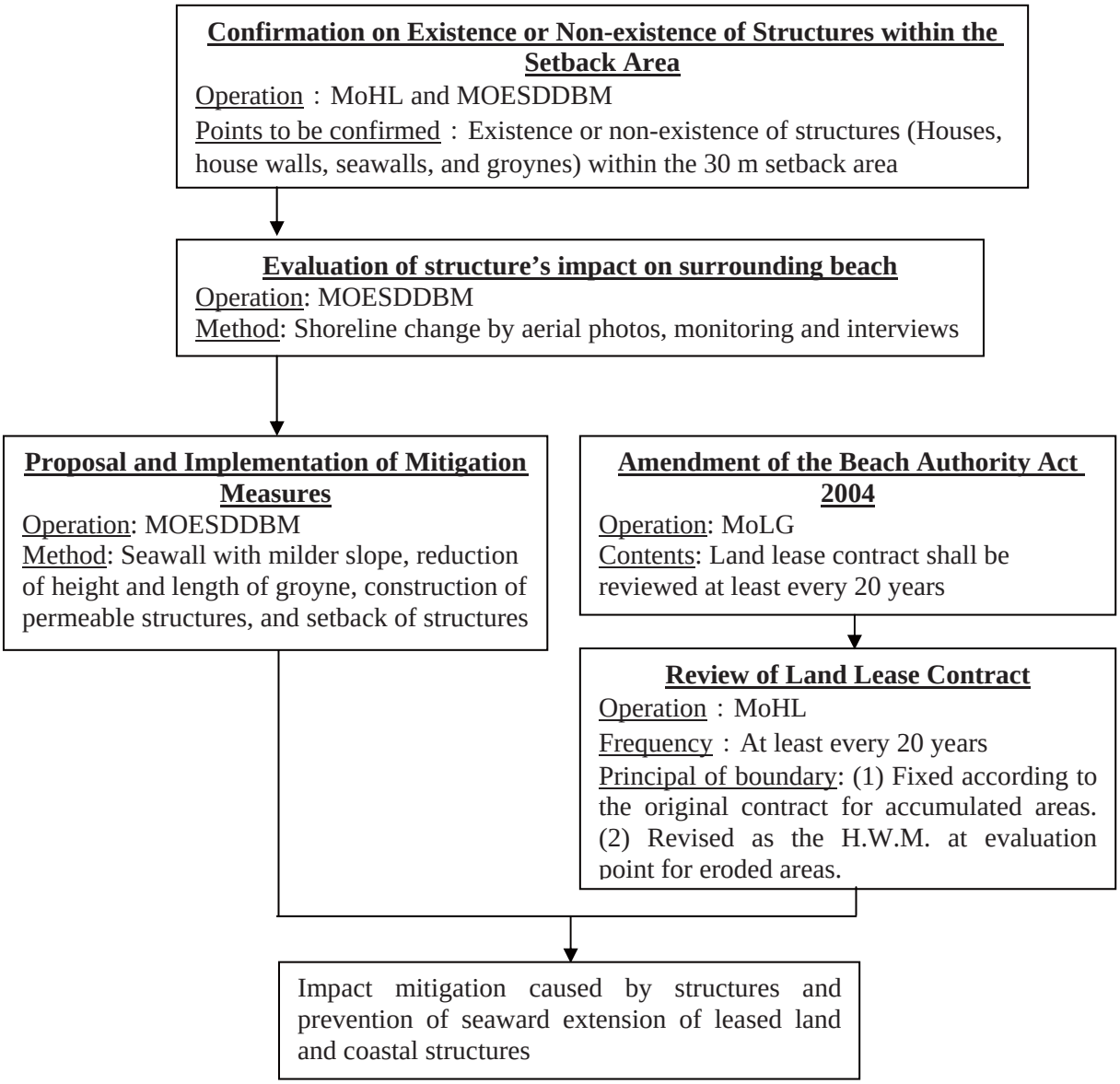
Actual conditions and issues	Proposal for revision of lease contract procedures
With lack of sufficient confirmation by MoHL and the District Council (MoLG), which the permission granting authorities for lease contracts and construction, even new buildings or structures had been constructed within setback area.	· The District Council (MoLG) shall confirm the declared area of construction by visiting the sites before construction. · For confirmation, District Council shall bring drawings that clarify construction boarders. These drawings shall be prepared by MoHL, based on the information supplied by owners.
Boundaries of leased area **1. <u>Boundary of accumulated area</u>** There are some cases that the boundary of the leased area (i.e. H.W.M.) was reviewed and extended seaward even though in principal it has to be at same position stipulated in the original contract in. **2. <u>Boundary of eroded area</u>** If erosion advanced after the lease contract, private owners can keep their ownership even if the land is underwater. This is going to be a problem for beach management that is continuous along the shore.	For the regulation on setbacks, the following items have to be clearly mentioned and well understood by MoHL. **1. <u>Boundary of accumulated area</u>** The seaward boundary of the leased area is identified as the border in the original contract and cannot be reviewed and extended even if the beach area has accumulated after the original contract. **2. <u>Boundary of eroded area</u>** The seaward boundary of the leased area has to be reviewed and revised to present the H.W.M. if the beach area has eroded.
Taking into account the beach profile and shoreline changes, the lease contract period of 60 years is so long that the regulation on setbacks cannot be newly applied during the contract period. This means that the setback rules become rules in name only, with no actual enforcement.	Taking into account the beach profile and shoreline changes, a re-examination period of the lease contract area shall be set every 20years even though the current lease period is 60 years. The lease period should be in sync with the beach management plan.
On overlapped areas of leased and public domain the lease contract has priority. The public domain is not secured in some coastal areas, especially in eroded areas.	In the area where the public domain is not secured, the government and/or owner shall prepare alternative public access such as walk ways.

Source: JICA Expert Team



Source: JICA Expert Team

Figure 7.3.7 Present and Proposed Procedures on Renewal of Lease Contract

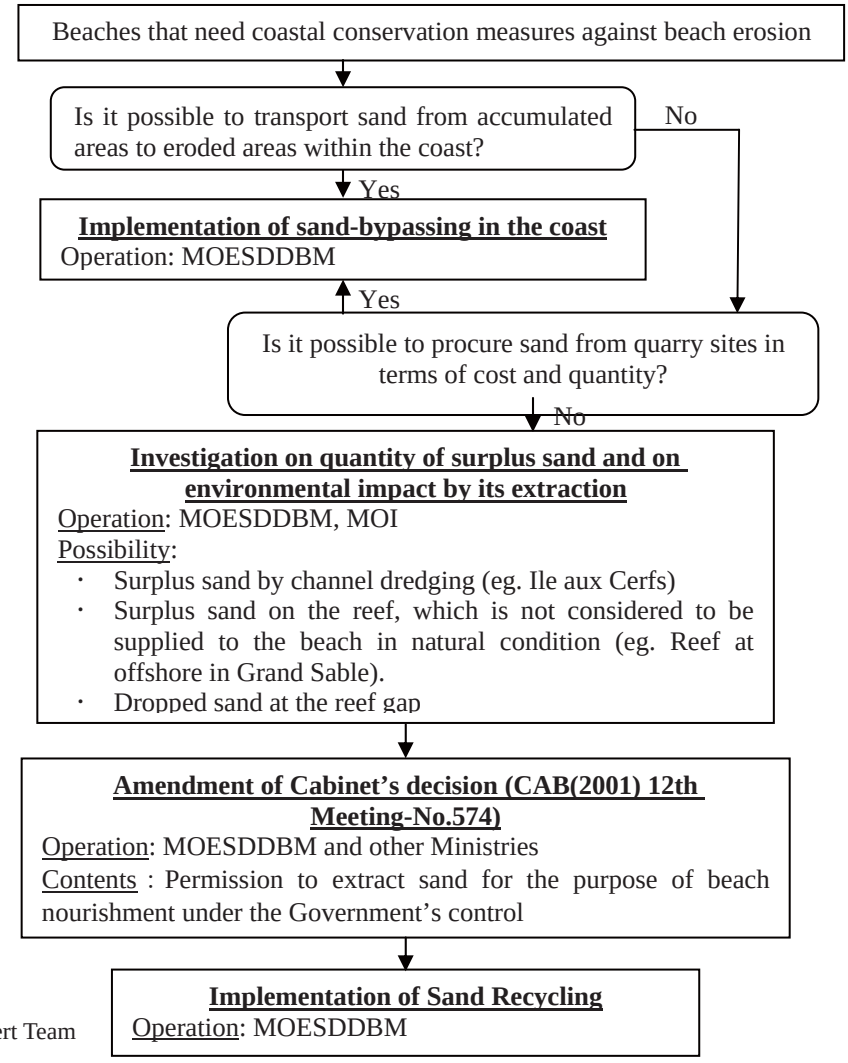


Source: JICA Expert Team

Figure 7.3.8 Mitigation Measures on Existing Coastal Structures

7.3.8 Management System of Sand Reuse

Mining of sand from lagoons was completely prohibited by the Cabinet Meeting's decision ("CAB (2001) 12th Meeting-No.574, Sand Extraction- Cabinet Memorandum"). The background to this decision, was the fact that there was a shortage of sand resources and deterioration of coral reefs caused by unregulated and unrestricted sand extraction over the years. In the sand budget analysis conducted in the Project, the total sand amount supplied to the beach was shown to have a tendency to increase over the last 50 years. In contrast, it was shown that serious beach erosion is advancing at some coastlines or at localised erosion at some coasts. Based on the concept of ICZM(Integrated Coastal Zone Management), it is proposed that some accumulated sand shall be used to nourish eroded beaches because the total amount of sand is increasing as a whole in Mauritius. To make this idea a reality, there is a need to amend the Cabinet decision. Extraction of sand for commercial purpose should not be allowed as unregulated extraction would be anticipated. However, it should be allowed with the public interest under the proper control by the government. One suggestion is to make an amendment to the decision by adding a sentence such as "the extraction of sand from beaches and/or lagoons is only allowed if it will be used for the purpose of restoration of natural sandy beaches under government control only after a thorough EIA is carried out and all measures are taken not to impact the environment".



Source: JICA Expert Team

Figure 7.3.9 Management System of Sand Reuse