Republic of Maldives
Ministry of National Planning, Housing and Infrastructure

Data Collection Survey on Climate-Related Disasters in the Male' Region in the Republic of Maldives

Final Report

March 2022
Japan International Cooperation Agency

Yachiyo Engineering Co., Ltd.
Oriental Consultants Global Co., Ltd.
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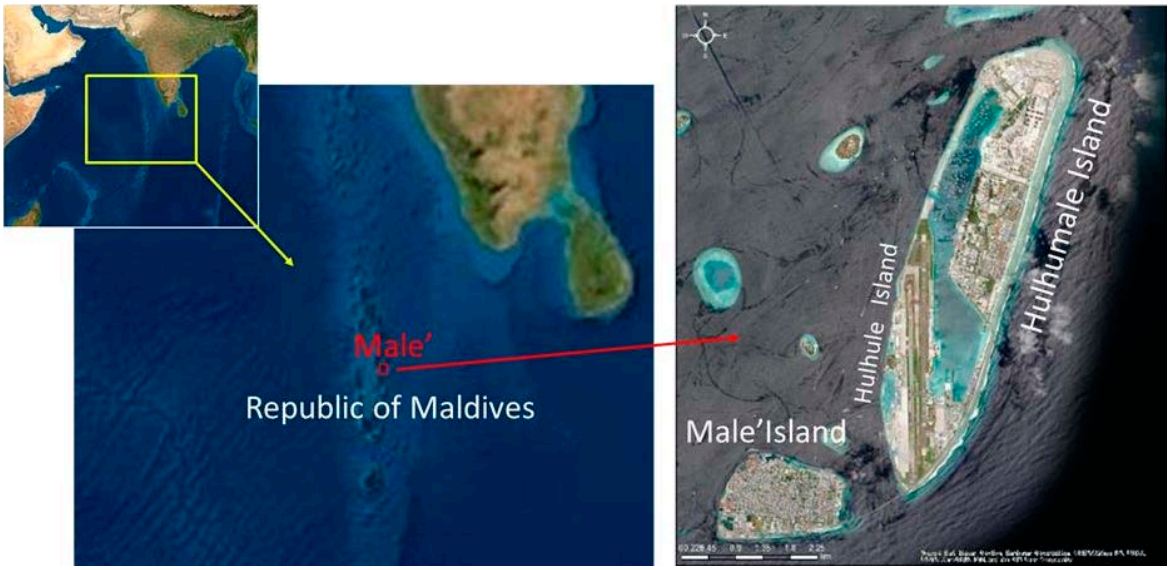
Location Map and Satellite Photos of the Surveyed Area



Location map of the surveyed area

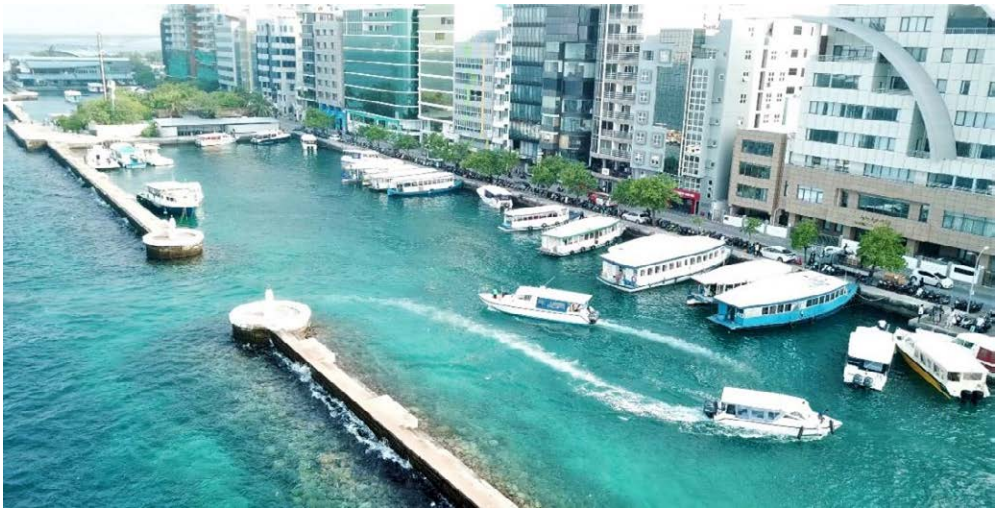
Satellite photo of Male'Island

Satellite photo of Hulhumale Island

Photos

Overview of Male' Island from the West (Mar. 2020)

East Coast of Male' Island (Dec.2021)



North Coast of Male' Island (Dec. 2021)

East Coast (Phase I) of Hulhumale Island (Dec. 2021)

East Coast (Phase II) of Hulhumale Island (Dec. 2021)

	
Road condition after rainfall on December 11, 2021 (Near Henveiru Ground in Majeedhee Magu Rd., Male')	Road condition after rainfall on December 11, 2021 (Central Part in Majeedhee Magu Rd., Male')
	
Road condition after rainfall on December 11, 2021 (Near Henveiru Ground in Majeedhee Magu Rd., Male')	Road condition after rainfall on December 11, 2021 (Central Part in Majeedhee Magu Rd., Male')
	
Underground Penetration System (Hulhumale Phase I Area)	Underground Penetration System (Hulhumale Phase II Area)

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Abbreviation

ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Cente
ADRC	Asian Disaster Reduction Center
CBDRM	Community Based Disaster Risk Management Program
CBDRR	National Community-Based Disaster Risk Reduction Framework
CERT	Community Emergency Response Team
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
EWBS	Early Warning Broadcast System
HDC	Housing Development Coporation
MCC	Male City Council
MCCPF	Maldives Climate Change Policy Framework (2014-2024)
MECCT	Ministry of Environment, Climate Change and Technology
MLSA	Maldives Land Survey Authority
MMS	Maldives Meteorological Service
MNDF	Maldives National Defence Force
MNPHI	Ministry of National Planning, Housing and Infrastructure
MNU	Maldives National University
MUDRP	Maldives Urban Development and Resilience Project
MWSC	Male' Water and Sewerage Company
MoE	Ministry of Education
NAPA	National Adaptation Program of Action (2006)
NDC	Update of Nationally Determined Contribution of Maldives (2020)
NDMA	National Disaster Management Authority
NDMA	National Disaster Management Act 2015
RDC	Road Development Corporation
SAARC	South Asian Association for Regional Cooperation
SAP	Strategic Action Plan
STELECO	State Electric Company
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WB	Wold Bank

SUMMARY

1. Overview of the Survey

Republic of Maldives is an island nation located in the Indian Ocean, southwest of India. These islands have an elevation of less than 2 meters and are susceptible to storm surges.The 1987 storm surge inundated the capital island of Male' and its surrounding islands, causing large damages both in human lives and economy. After the storm surge, the Japanese government provided grant aid to build seawalls around Male' Island, which was completed in 2002.

In the 2004 Indian Ocean Tsunami, the seawall was effective in reducing the force of the tsunami and there was no loss of life even though about 60% of the island was inundated.On the other hand, inland flooding occurs every year in Male'. Due to the foreseen rise in sea level and increase in rainfall intensity caused by climate change, the risk from storm surges and inland floodeing is expected to worsen.

With this background, this survey was implemented to collect and confirm information on the damages caused by climate-related disasters, the current status of infrastructure that contributes to the reduction of disaster risks in the Male' metropolitan area (Male' Island and Hulhumale Island), and to investigate the direction of future cooperation to Maldives in DRR and to climate change adaptation measures.

In this survey, the Ministry of National Planning, Housing and Infrastructure (MNPHI) is the main agency concerned, while information was collected from other agencies such as HDC, according to the survey items.

2. Current Situation of Climate-Related Disasters and the Systems for Countermeasures

2-1 Overview of Natural Conditions and Climate-Related Disasters

The capital city of Male' has a small area of 1.8 km^2 but its population is over 133,000 (UN, 2017) with very high population density, which is about five times as high as Tokyo's central district.To ease the over crowding on Male' Island, the Hulhumale Development by the Housing Development Corporation (HDC) has been underway with plans to house up to 240,000 people by 2050. At present, about 50,000 people live in the island.

The annual rainfall in the capital region is 2,365 mm and cyclones pass through the Maldives between April and December. For the island of Male', the risk of storm surge is not excessively high due to the effectiveness of the sea walls, but inland flooding is an annual occurrence. On the national level, storm surges occurred twice in the 20-year period of 1987-2006, once per decade, while in the last 14 years, 2007-2021, the frequency of storm surges and inland flooding increased to 0.7 time per year.

2-2 Policies Related with Disaster Management and Climate Change

The Disaster Management Act 2015 was enacted in 2015 as the foundation for the disaster management system in the Maldives. The Strategic Action Plan (SAP) (2019-2023), which sets out the development direction and policy framework for the whole of the Maldives for the five-year period 2019-2023, stipulates policies for climate resilience, including building climate resilient infrastructure and communities to address current and future vulnerabilities.

National strategies for disaster risk reduction and climate change adaptation include the National Adaptation Programme of Action (NAPA) in 2006, followed by the Strategic National Action Plan for Disaster Risk Reduction and Climate Change Adaptation (SNAP) 2010-2020. The Maldives Climate Change Policy Framework (MCCPF 2014-2024) states that climate change measures will be integrated into all relevant sectoral plans. Additionally, a Nationally Determined Congtribution for the Maldives (NDC Update (2020)) has been prepared in 2020. NDC outlines the specific implementation of climate change mitigation and adaptation measures.

2-3 Agencies Concerned with Disaster Management

The outline of the agencies concerned with the storm surge, inland flooding and climate change in the metropolitan area is summarized below.

Agencies concerned with disaster management

Coordinating body
National Disaster Management Authority：NDMA NDMA coordinates disaster management activities of concerned stakeholders at the national level.
Implementing agencies
Ministry of National Planning, Housing and Infrastructure：MNPHI MNPHI develops plans for projects related to storm surge and flooding control.
Housing Development Corporation：HDC HDC is implementing the development of Hulhumale Island.
Male' Water and Sewerage Company：MWSC MWSC constructs and maintain the stormwater drainage, water supply and sewerage systems according to the plans developed by MNPHI.
Maldives Land Survey Authority：MLSA MLSA creates maps of Maldives, including the metropolitan area.
Male' City Council：MCC The MCC cleans road drainage facilities.
Disaster management administration and disaster information
Maldives Meteorological Services：MMS The MMS conducts weather observation across the country and issues weather forecasts / warnings.
Environmental administration
Ministry of Environment, Climate Change and Technology：MECCT MECCT is responsible for sewage, renewable energy, and the environment. A new department of climate change has recently been established.
DRR education, research and human resource development
Ministry of Education：MoE MoE implements DRR education in schools.
Maldives National University：MNU The Bachelor of Civil Engineering exists in the Faculty of Science and Engineering at MNU.

3. Climate–Related Disasters, the State of Infrastructure and Cooperation Needs in the Male' Region

3-1 Storm Surge

(1) Natural condition

In order to cope with the increasing population of Male' Island, the surrounding lagoons were reclaimed from 1979 to 1986 to create land. Since the land reclamation of Male' Island had reached its limit, the land reclamation of the lagoon to the northeast of the airport island began to create so called Hulhumale Island in 1997. Phase I (188 hectares) was completed in 2002, and Phase II (240 hectares) was completed in 2016.

(2) Outline of the disaster

Before 1986, there was no record of damage due to storm surge in Male' Island. In 1987, a 3 m high wave hit the island, causing severe flooding and extensive damage in the south of the island. And in 2004, the Indian Ocean Tsunami hit the Maldives, causing extensive damage with 108 people killed or missing nationwide. However, the newly completed permanent seawalls on Male' Island reduced the energy of the tsunami. Although there were some unusual overtopping waves and the island was flooded, there was little human or property damage. Since then, no storm surge disaster has occurred.

(3) Current status and issues of coastal protection facilities

The 1987 disaster revealed that the coastal protection facilities on Male' Island were extremely vulnerable, and 10 detached breakwaters were urgently constructed off the south coast with Japanese

grant aid. Subsequently, a development study for the seawall construction on Male' Island was conducted. And from 1993 to 2002, permanent seawalls were constructed with grant aid in the following order: west seawall, east seawall, south seawall, and north seawall.

The current status of seawalls in Male' Island was confirmed during the survey. Although some of the seawalls have been changed since 2002 based on the new development plan of the Government of Maldives in the coastal area, it was confirmed that the seawalls are fully fulfilling their functions as coastal protection facilities. However, some parts of the east coast showed overtopping of waves and flying sand, and it was judged that countermeasures were necessary. In addition, a part of the north seawall collapsed when the tsunami hit and was repaired by the tsunami restoration project. But the upper blocks of that part of the seawall shifted due to the excessive towing force of ships. There is no problem in terms of disaster prevention function, but it is judged that this part should be repaired. The north seawall is a steel sheet pile structure that was built more than 40 years ago and seems to be aging. Since this is also an important coastal road protection, it is necessary to reinforce it before a disaster occurs. The west and south coasts were judged to have no particular problems in terms of disaster prevention functions.

Permanent seawalls have been constructed for the causeway connecting Airport Island and Hulhumale Island and for the coastal protection facilities on the north and west coasts of Hulhumale Island. On the east coast, the shoreline of the east coast of Hulhumale Island has been built about 150m away from the reef edge of the open sea. There is no artificial seawall and it is not considered to be a problem in normal waves, but there are still issues of disaster prevention due to erosion in some places.

(4) Impact of climate change

As for the sea level rise, based on the data from IPCC and MEE, the Government of Maldives predicts that the sea level rise in Male' Island will be 50 cm (5 mm/year) by 2100. In this study, initial consideration was given to the future coastal protection facility plan for the Male' metropolitan area based on this value.

(5) Cooperation needs

Hulhumale Island is an important metropolitan area where 240,000 people are expected to live in the future. The east coast is only a sandy beach and is extremely vulnerable as a coastal protection facility. Considering the future rise in sea level, it is necessary to plan a permanent seawall now. The east and north coasts of Male' Island are in need of support as there are areas where the existing seawalls need to be reinforced.

East Coast of Hulhumale Island (Phase I area)

3-2 Inland Flooding

(1) Natural conditions

Both Male' Island and Hulhumale Island are flat and low-lying lands with elevations of around 1 to 2 m from the mean sea level.

From the rainfall data from January 2015 to August 2021, no large annual fluctuations in monthly rainfall are confirmed. On the other hand, the graph of daily maximum rainfall of the month shows the daily rainfall of more than 100 mm has been recorded four times, but daily maximum rainfalls in 2018 and 2019 increased, compared to 2015 and 2016. It has been pointed out that the number of rainfall days is decreasing, while the amount of rainfall in a short period of time is increasing in Male'.

(2) Overview of the disaster

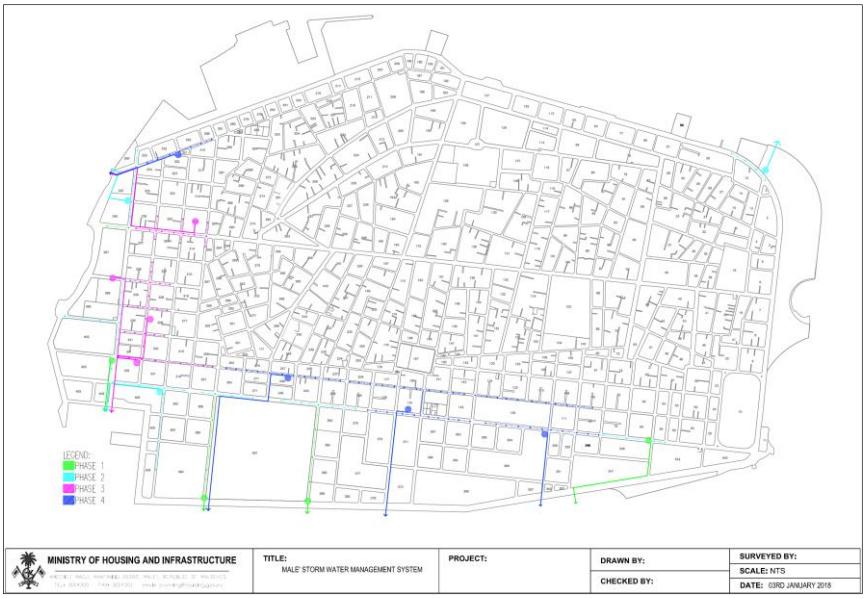
Since the topography of Male' Island is flat and low in total and there are no depressed areas where rainwater tends to gather, it can be inferred that the floods do not cause as much damage as ones of tidal wave / storm surge, and that it is not a life-threatening inland flood. In the past inundations, it has been

only underfloor inundation, but these inundations are a factor that hinders the socio-economic activities of the dense Male'. Therefore, any improvement for this situation is required. The road floods have occurred with the main reasons of 1) insufficient road side drains, 2) insufficient capacity of drainage pumps, and 3) lack of O&M for stormwater drainage facilities, but the road flooding has been resolved within 3 hours.

Compared to the fully developed Male' Island, the infiltration area is sufficiently secured in Hulhumale, and the infiltration capacity of sand is still sufficient, so no significant inland water inundation has occurred. However, according to HDC, the stormwater storage capacity in the basin has been decreasing in recent years, and it seems that floods occur after 1 to 2 hours of rainfall. This situation is getting worse year by year.

(3) Current status and challenges of disaster prevention infrastructure

On Male' Island, there are 15 drainage pumping stations (PSs) constructed from 2014 to 2018, road gutters which was constructed around 20 years ago, and the small gutters constructed more than 40 years ago. The funds used for the stormwater drainage project were allocated from the national budget, and these PSs have been operated by MWSC.



Source: MCC

Pumping station and drainage pipes on Male' Island

For the development of Hulhumale Island, the HDC has prepared a city planning and has also been developing drainage facilities. On Hulhumale Island, drainage channels, drainage pipes, and pump facilities, etc. have not been developed, and rainwater is drained by underground infiltration.

The stormwater drainage facilities on Male' Island are maintained based on an annual plan, but road drainage facilities are rarely maintained. There is an opinion that MWSC staff would like to introduce SCADA system for remote monitoring to improve efficiency, as the number of vehicles has been increasing and it is difficult to maintain and manage drainage facilities (operation monitoring of PSs).

In Male' Island and Hulhumale Island, the World Bank (WB) has been implementing the "Maldives Urban Development and Resilience Project (MUDRP)" since 2020. MUDRP consists of the following main components of 1) sewage treatment facility in Hulhumale Island, 2) stormwater drainage and storage facilities on Male' and Hulhumale islands, and WB focuses on Male' Island for 2) at present. 2) includes stormwater management master plan in Male' and Hulhumale Islands.

(4) Climate change impacts

Rainfall in the Male' region is forecasted to increase to 150-200% between 2021 and 2050, and to 200-300% between 2082-2100, respectively, in comparison with rainfall in 2007.

(5) Cooperation needs

On Male' Island, WB has been conducting capacity evaluation and facility development projects for stormwater drainage facilities throughout the island, and there is little room left for cooperation for the development of stormwater drainage facilities. According to the WB, they are not considering projects for O&M and training related to stormwater drainage. Therefore, there remains possibility of cooperation by Japan in strengthening management capacity and the provision of equipment regarding inundation prevention / control.

Regarding Hulhumale Island, although stormwater drainage facilities have not been developed so far, the ground would be covered with pavement and buildings due to the progress of urbanization in the future, and the function of storage and infiltration in the catchments would decline due to the decrease in infiltration area. It leads to the needs of HDC for stormwater runoff analysis and planning of stormwater drainage facilities were identified to cope with the increase in rainfall due to the effects of future climate change.

3-3 Human Resource Shortage

(1) Availability of staff with expertise in agencies

The agencies lack engineers in the fields such as storm surge and inland flooding. The universities in the Maldives do not provide sufficient practical knowledge in these fields, which leads to the difficulty in these agencies' recruitment of technical staff. Most of the engineers in these agencies have obtained their degrees abroad, and the number of the engineers is limited. Engineers with such practical expertise are not experienced in the feilds

(2) Current status of education and research activities of higher education

The Bachelor of Civil Engineering in the Faculty of Engineering, Science and Technology at Maldives National University (MNU) provides basic knowledge on coastal engineering and urban drainge. However, it does not adequately address the specific issues in practice. It would be necessary to supplement the course content and expand research field so that students can respond to the problems occurring in the metropolitan area.

(3) Cooperation needs

As mentioned above, challenges exist in the development of human resources with expertise of coastal engineering and urban drainage. There is a need for cooperation in the following areas: 1) Strengthening the technical skills of ministry engineers 2) Education and research on practical aspects in higher education institutions

3-4 DRR Education in Schools

(1) Current status of DRR education

DRR education has not yet been made into a curriculum, and the content at this stage is inadequate, limited to teaching the types of disasters. Teachers do not have sufficient knowledge about disaster management.

(2) Awareness of citizens and politicians on DRR

The importance of disaster management is not sufficiently understood by citizens and politicians. It is necessary to raise their awareness. If students learn about disaster management at schools, they will spread the knowledge to their families and neighborhoods. It is expected that this will change the mindset of the society and those involved politics, leading to a driving force for mainstreaming disaster risk reduction.

(3) Cooperation needs

DRR education should be promoted in order for students to have a proper understanding of the current situation of disaster occurrence in the metropolitan area, the mechanism of occurrence, disaster

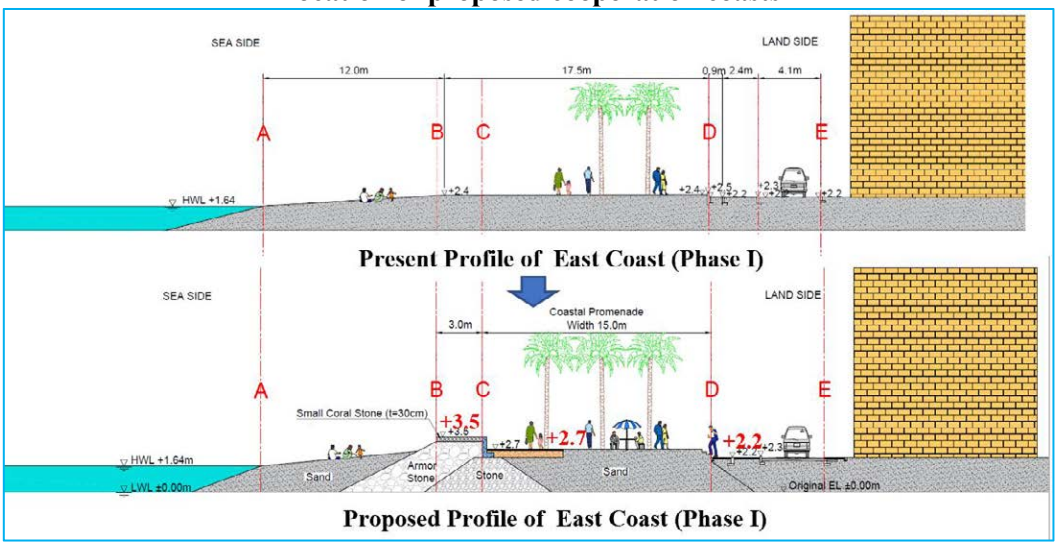
management measures, and the impact of climate change, At present, there are no curricula for this purpose and no guidelines for teachers. There is a need for cooperation to address this situation.

4. Contents of Cooperation

4-1 Storm Surge

Based on the results of the current status survey, cooperation plans for four coastal areas were prepared. (1) a new seawall (2,300 m) in the Phase I area on the east coast of Hulhumale Island, (2) a new seawall (1,600 m) in the Phase II area, (3) reinforcement (100 m + 140 m) on the east coast of Male' Island, and (4) restoration (95 m) and reinforcement (609 m) of the existing seawall on the north coast of Male' Island were selected for initial consideration as cooperative projects. A tentative image of the proposed seawall for the east coast of Hulhumale Island is shown below.

Location of proposed cooperation coasts



Tentative image of the proposed seawall for the east coast of Hulhumale Island

4-2 Flooding

Possible cooperation by JICA for inland flooding is discussed for Male' Island and Hulhumale Island.

(1) Technical cooperation by provision of equipment for Male' Island

In fields that are not currently covered by the WB project, the possible cooperation for which needs were recognized in this survey include monitoring of existing pump facilities by means of providing equipment (SCADA System). In addition, a need exists to provide the cleaning equipment since there is a concern that the cross-sections are clogged due to insufficient operation and maintenance (O&M) of the existing drainage gutters and pipes (e.g. improvement of gratings and cleanings). It is desirable to

transfer these technologies in an integrated manner. According to MNPHI, it is possible to procure highly necessary materials and equipment with their budget. Therefore, it is possible to dispatch expert to MNPHI ((3) below) first and procure equipment with their own funds, depending on the urgency.

(2) Technical cooperation by preparation of stormwater management plan for Hulhumale Island

As for Hulhumale Island, stormwater drainage facilities (pipes, drainage channels, pump facilities) have not been developed at this time, and the island relies on the underground infiltration capacity. In the future, more ground surface would be covered with pavement and buildings due to the progress of urbanization, and the infiltration area would decrease. It is considered necessary to prepare a comprehensive stormwater management master plan as a first step to address these issues. This is highly concerned by HDC but the coordination with WB, which focuses on stormwater management works in Male' Island at present but may prepare master plan for Hulhumale Island, is required.

(3) Technical cooperation to stormwater related agencies by dispatching Expert

As in the case of (1) above, the WB is not currently involved in dispatch of drainage experts. The expert to support the preparation of stormwater drainage plans and improve the O&M and management capacity of related organizations was confirmed to be highly needed by MNPHI in this survey, and it is possible to conduct it prior to (1) and (2) above. When implementing the dispatch of expert, the advices on stormwater management not only for Male' Island but also for Hulhumale Island could be considered to include in the scope.

(4) Summary of possible cooperation

Three possible cooperation above are summarized below with the project name (tentative), possible assistance forms, implementing agencies, assumed project terms, and prospectivity for each project.

List of possible cooperation for flooding measures

No.	Project Name (tentative)	Aid Scheme	C/P Agency	Project Term	Prospectivity
1	Improvement of Operation and Maintenance Capacity for Stormwater Management Sector in Male' Island	T/C	MWSC, MCC /MNPHI	24 months	High
2	Stormwater Drainage Master Plan Study for Hulhumale Island	T/C	HDC	24 months	Middle
3	Dispatch of stormwater management expert	Dispatch of expert	MNPHI	12 months	High

Note: T/C = technical cooperation
Source: JICA Survey Team

4-3 Strenghthening the human resource capacity of the agencies related with DRR infrastructures

Strenghthening the human resource capacity of the agencies

Overall goal
Development and maintenance of DRR infrastructure will be sustained.
Project purpose
The human and organizational capacity required for the development and maintenance of DRR infrastructure is strengthened.
Outputs
1. to acquire basic knowledge about planning, design and maintenance of DRR infrastructure 2. to understand the actual phenomena on the sites and to acquire practical skills for planning, design, and maintenance 3. to develop a design standard and a maintenance guideline
Activities
1-1 Learning and practice of basic knowledge on planning and design 1-2 Learning basic knowledge on maintenance 2-1 Learning the mechanism of actual phenomena on the sites, such as coastal erosion, inland

flooding, / structural damage, and their countermeasures 2-2 Learning the operation and maintenance methods based on actual phenomena: inspection, record keeping, patrol, image recording, archiving of technical matters, etc. 3-1 Customization of Japanese guidelines / standards for application to the Maldives 3-2 Development of planning and design standards and maintenance manuals for coastal engineering and urban drainage in the Maldives Inputs include the dispatch of experts and visiting Japan through technical cooperation.
Relevant agencies
The agencies related to DRR infrastructure such as MNPHI and HDC

4-4 Education and Research on Practical Aspect in Higher Education

Introduction of education and research on practical aspect in higher education

Overall goal
Human resources needed for the development and maintenance of DRR infrastructure are allocated properly..
Project purpose
A practical education and research system for coastal engineering and urban drainage are established at the MNU.
Outputs
1. Curriculum and materials for practical education/research on coastal engineering and urban drainage are developed at the bachelor of civil engineering in MNU 2. The faculites understand the application methodology of the developed curriculum and materials.
Activities
1-1 Dispatch of Japanese university faculties, research institute staff, and firm engineers specialized in the fields of coastal engineering and urban drainage 1-2 Creation of practical teaching/research materials and curricula to identify issues and solve problems actually occurring on the sites 2-1 Support for classes, exercises, researches and paper presentations: The target of support is faculty members, but students and government engineers participates in the classes, exercises and research activities. Credits are granted them on short-term intensive classes 2-2 Trainings in Japan for MNU faculty members and university staff

4-5 DRR Education in Schools

DRR education in schools

Overall goal
Students' awareness of DRR is enhanced.
Project purpose
The capacity of teachers in providing DRR education is improved
Outputs
1. Study guideline, curriculum, textbooks and teachers guideline on DRR will be developed. 2. Teachers training for DRR is prepared.
Activities
1-1 Creation of the study guideline for school DRR 1-2 Creation of teachers guideline 1-3 Preparation of teaching materials 2-1 Preparation of scheme for teachers training 2-2 Training implementation 2-3 Revision of teachers training scheme based on DRR education implementation Input: Dispatch of experts, Training in Japan for Maldivian personnels (MoE staff and school teachers)

Chapter1 Overview of the Survey

1-1 Background

The Republic of Maldives (hereinafter referred to as "Maldives") is an island nation located in the Indian Ocean, southwest of India. These islands, which form coral atolls, have an elevation of less than 2 meters and are susceptible to high waves and storm surges.

The 1987 storm surge inundated the capital island of Male' and its surrounding islands, causing damage estimated at US$ 5 million[1]. After the storm surge, the Japanese government provided grant aid to build a coastal revetment (4.8 km in total length) around Male' Island, which was completed in 2002.

In the 2004 Indian Ocean Tsunami, the maximum offshore tsunami height was estimated to be 1.85m, and the water level in front of the south seawall peaked at more than L.A.T + 3m, while the ground level at Male' Island was less than + 2m. However, the seawall was effective in reducing the force of the tsunami[2] and there was no loss of life even though about 60% of the island was inundated.

On the other hand, inland inundation occurs every year in Male'. Due to the expected rise in sea level and increase in rainfall intensity caused by climate change, the risk from storm surges and inland inundations is expected to worsen. In particular, in the metropolitan area, which is the capital of Maldives and where more than 30% of the population is concentrated, the socioeconomic impact of these meteorological disasters is significant, and disaster countermeasures, both structural and nonstructural, need to be strengthened[3].

In view of such climate related disaster risks, the Government of Maldives has been developing climate change adaptation measures to reduce climate-related disaster risks. The Disaster Management Act 2015 was enacted in 2015, and the National Disaster Management Authority (NDMA) was established in 2018. The Strategic Action Plan 2019-2023, released in 2019, includes policies related to climate change and disaster risk reduction (DRR). It outlines the legal framework, strengthening of government institutions, and policies for mainstreaming DRR in regional planning.

With this background, this survey was conducted to review and understand the disaster risks facing the metropolitan area and the status of existing facilities for DRR, and to identify cooperation projects needs from various perspectives.

1-2 Objectives

The purpose of this study is to collect and confirm information on the damages caused by climate-related disasters, the current status of infrastructure that contributes to the reduction of disaster risks in the Male' metropolitan area (Male' Island and Hulhumale Island), and to investigate the direction of future assistance to the Maldives in DRR and to climate change adaptation measures.

1-3 Method of the Survey

1-3-1 Surveyed organizations and overview of information collection

In this survey, the Ministry of National Planning, Housing and Infrastructure (MNPHI) is the main agency concerned, while information and opinions were collected from other agencies according to the survey items. The table below shows the agencies surveyed and the main points of information collected.

Table 1-3.1 Organizations surveyed and information collected

Ministry of National Planning, Housing and Infrastructure (MNPHI)
Needs for improvement of coastal revetments constructed with Japanese ODA, countermeasures against high waves and storm surges in Hulhumale Island, countermeasures against inland inundation in Male' Island, future plans for disaster prevention facilities, maintenance of the facilities, and securing technical human resources
Housing Development Corporation (HDC)
Progress of development on Hulhumale Island, current condition of inland flooding, damages caused by storm surge / coastal erosion and their countermeasures, status of coastal erosion on the east coast

1)JICA: Basic design study report on the project for the seawall construction in Male' Island (Phase II) in the Republic of Maldives, 1996
2) Koji Fujima et al.: Preliminary Report on the Survey Results of 26/12/2004 Indian Ocean Tsunami in the Maldives, April 2005
3) Government of Maldives, Strategic Action Plan 2019-2023, https://storage.googleapis.com/presidency.gov.mv/Documents/SAP2019-2023.pdf

Maldives Water and Sewage Corporation (MWSC)
The current status of inland inundation / drainage facilities, the details of future drainage plans, and planning / construction / maintenance systems in Male’
Maldives Land Survey Authority (MLSA)
Confirmation of the availability of electronic elevation models and plans for their creation, the specifications of existing topographic maps (scale, contour interval) for Male’ and Hulhumale Islands
Ministry of Environment, Climate Change and Technology (MECCT)
Climate change and disaster risks in the Maldives, tidal range and rainfall intensity, input on environmentally friendly structural measures
Maldives Meteorological Services (MMS)
Tidal level and rainfall records around the metropolitan area, meteorological observation system, communication flow of meteorological information to relevant ministries and citizens
National Disaster Management Authority (NDMA)
Organizational structure for disaster preparedness/response/rehabilitation procedures in the event of a disaster, information flow of command, current status of mainstreaming DRR (disaster risk reduction)
Ministry of Education (MOE)
DRR education, training for teachers on DRR education, damage caused by climatic related disasters in schools, emergency response guidelines of schools
Maldives National University (MNU)
Curriculum of the faculty of civil engineering, education and research on coastal engineering, urban drainage, hydrology and hydraulics
World Bank (WB)
Details and progress of inland inundation prevention and disaster management in the ongoing Urban Development and Resilience Project (2020~2026)

1-3-2 Collection of other information

In addition to collecting information from relevant agencies, the following surveys were conducted in the field.

(1) Visual survey on foot and photography on wave and storm surge effects and coastal erosion (including drone photography[4)])
- Areas that need to be improved on the east and north coasts of Male' Island (3 locations)
- Hulhumale Island causeway, approx. 3.3 km (overwash is occurring)
- East coast of Hulhumale Island, about 3.9 km

(2) Coastal survey from the sea side by boat
The entire perimeter of the coasts of Hulhumale Island and Male’ Island were observed and photographed from the sea side on a boat.

(3) Coastal survey from the sea side by water scooter
The east coast of Hulhumale Island was observed and photographed from a water scooter for about 3.9-km long inside the reef.

(4) Coastal transect survey
A transect survey of 7 lines (30~35m/line) was conducted along about 3.9km- east coast of Hulhumale Island.

(5) Visual survey on foot and photography of inland inundation in Male’ and Hulhumale Islands
In Male’ Island, the survey activities were conducted mainly in the southwest area where inland water frequently occurs.

[4)] It was conducted with the permission of the Ministry of National Defense and MNPHI. The specific locations and contents are described in detail in Chapter 4.

Chapter2 Current Situation of Climate-Related Disasters and the Systems for Countermeasures in the Male' Region

2-1 Overview of Natural Conditions and Climate-Related Disasters

The Maldives is an island nation in the Indian Ocean, southwest of India, extending 950 km from north to south and 160 km from east to west, comprising of 26 atolls and 1,192 islands of various sizes, of which about 200 are inhabited. The total land area is 298 km^2 and the total coastline is 644 km. [1)] The coastline length to total land area is 2.15 km/km^2, which is about 20 times longer than that of Japan (0.10 km/km^2). The islands are widely dispersed in the sea area, so the difficulty of coastal management of inhabited islands in the Maldives is obvious even when uninhabited islands are excluded.

The disaster risk in the Male' region (Male' and Hulhumalé Islands) is on the rise. The annual rainfall in the capital region is 2,365 mm, the temperature is 27-28°C throughout the year and cyclones pass through the Maldives between April and December. According to the IPCC Sixth Assessment Report (2021), the temperature is expected to increase by 1.5-4.4°C between 2081 and 2100 compared to the average of 1850-1900, while the sea level is projected to rise by 39-71 cm in the Special Report on the Oceanic and Cryosphere (2019).[2) 3)] The intensity of disasters (hazards) is expected to increase in the future.

In addition, the vulnerability of the Male' metropolitan area is also increasing. One third of the total population of Maldives (534,000 (Government of Maldives, 2019)) resides in the area, and the capital city of Male' has a small area of 1.8 km^2 but its population is over 133,000 (UN, 2017). Its high population density and the very low altitude of 1.00-1.43 m above sea level result in heighten disaster risks.

The annual economic growth rate of the Maldives is 5.9% (Maldives Monetary Authority, 2019), and the population density of Male' Island is 73,800/km^2, which is about five times as high as Tokyo's central district of 15,400/km^2 (Tokyo Metropolitan Government, Bureau of General Affairs, 2022). Thus, Male's assets and high population density increase its vulnerability to climate hazards.

Hulhumale Island has been developed since 1997 as a settlement from the overcrowded Male' Island, with a current total area of 4.03 km^2. [4)] The altitude is low, between 1.8 and 2.0 m above sea level. At present, about 50,000 people (HDC, 2021) live in the area. To ease the overcrowding on Male' Island, the Hulhumale Development Project by the Housing Development Corporation (HDC) has been underway to build housing complexes and commercial facilities[5)], with plans to house up to 240,000 people by 2050.

Under such natural and social conditions, the Male' metropolitan area, with its high concentration of population and assets, is experiencing damages caused by tidal waves, storm surges and inland flooding; furthermore, the risk to human life and property is very high. For the island of Male', the risk of storm surge and tidal wave is not excessively high due to the effectiveness of the sea walls, but inland flooding is an annual occurrence.

The table below lists the climate-related disasters of recent years. On the national level, storm surges and tidal waves occurred twice in the 20-year period, 1987-2006 (once per decade), while in the last 14 years, 2007-2021, the frequency of storm surges, tidal waves and inland flooding increased to 0.7 time per year. One notable disaster event in the Male' metropolitan area was the 1987 storm surge, which inundated the surrounding islands, including Male'. In 2004, an earthquake off the Indonesian island of Sumatra triggered an Indian Ocean tsunami that inundated about 60% of the Male' Island. The maximum tsunami height was estimated to be between 1.39m and 1.85m[a)].

1) Maldives Natural Disaster Profile：https://ndmc.gov.mv/dmsdocument/2
2) Ministry of Environment, IPCC「Special Report on Marine and Cryosphere」summary (2020), p.79, 2020
mhttp://www.env.go.jp/Hearth/ipcc/special_reports/srocc_overview.pdf
3) Second National Communication of Maldives to the United Nations Framework Convention on Climate Change, Oct. 2016, p.32
4) Housing Development Corporation, 2019 Annual Report, p.9
5) Housing Development Corporation, Company Presentation, May 2021, p.4
a) Koji Fujima et al.: Preliminary Report on the Survey Results of 26/12/2004 Indian Ocean Tsunami in the Maldives, April 2005

Table 2-1.1 History of climate disasters in the Maldives and Male' Capital Region

Date of disaster	Disaster type	Locations	Death	Victims	Total damage
1987.4[1)]	Storm surge	***Male'*** surrounding islands			5 million USD
1988.6,7[1)]	Storm surge	***Male'*** surrounding islands			
2004.12.26[1), 2)]	Indian Ocean Tsunami	***Male'*** ***Hulhumale*** and other	108 people	27,214 people	470 million USD (62% of GDP)
2005～ Every dry season[2)]	Insufficient water	92 islands			1.4 million USD or more
2007.5.15[2)]	Storm surge	Regional islands		1,649 people	
2012.10 末~11[3)]	Flooding by cyclone	***Male'*** 28 island		33,826 people	133,090USD
2010. 7.22[4)]	Storm surge	***Male'***			
2012.10~11[5)]	Heavy rain	20 islands			
2013.10~11[5)]	Heavy rain	20 islands			
2014.5~6[5)]	Storm surge	21 islands			
2014.5~6[5)]	Heavy rain, strong winds	21 islands			
2015.5~6, 11~12[5)]	Heavy rain, strong winds	13 islands			
2016.5[6)]	Storm surge	5 islands		70 household	Economy Infrastructure Agriculture
2016.11[6)]	Flooding	Addu City		172 household	Economy Infrastructure Agriculture
2017.12.2[3)]	Flooding, storm surge by cyclone	62 islands			Infrastructure Agriculture[6)]
2018.7,9[6)]	Storm surge	8 island		9 household	Economy Infrastructure Agriculture
2018.12[6)]	Flooding	***Male'***		3 household	Economy Infrastructure Agriculture
2019.1,2,6,7,8,9,10[6]	Flooding	12 islands		53 household	Economy Infrastructure
2019.5.30[2)]	Flooding	Regional islands		1,800 people	
2019.9[6)]	Flooding	***Male'***		28 household	Economy Infrastructure
2019.6,7,8[6)]	Storm surge	26 islands			Economy Infrastructure Agriculture
2020.1,2,5,7[6)]	Storm surge	7 islands		69 household	Economy Infrastructure Agriculture
2021.1,2,3,5,7[6)]	Storm surge	20 islands		185 household	Economy Infrastructure Agriculture
2021.1,2,5,9,10[6)]	Storm surge	6 islands		16 household	Economy Infrastructure Agriculture
2021.5.16[2)]	Storm surge by cyclone	Regional islands		1,320 people	Economy Infrastructure Agriculture
2021.12[7)]	Flooding	***Male'***			Economy

1) JICA: Basic design study report on the project for the seawall construction in Male' Island (Phase II) in the Republic of Maldives, 1996
2) EM-DAT, (1980~2021)
3) ADRC(https://www.adrc.asia/nationinformation_j.php?NationCode=462&Lang=jp&NationNum=36)
4) https://www.env.go.jp/nature/biodic/coralreefs/icccrc2013/pdf/year2013630/section4/roger.pdf
5) https://www.ndmc.gov.mv/downloads/natural-disaster/
6) Incident report to NDMA-EOC, 2016~2020
7) MMS

Figure2-1.1 Japanese seawall on the north side of the artificial beach on the east coast of Male' Island, 10 December 2021

Figure2-1.2 Inland flooding in Male' City, 11 December 2021

2-2 Policies related with disaster risk reduction and climate change

The Disaster Management Act 2015 was enacted in 2015 as the foundation for the disaster management system in the Maldives. Under the Act, the Government of the Maldives established the National Disaster Management Council, chaired by the President, and the National Disaster Management Authority (NDMA) was established in 2018[6].

The Strategic Action Plan (SAP) (2019-2023), which sets out the development direction and policy framework for the whole of the Maldives for the five-year period 2019-2023, stipulates seven policies for climate resilience, including building climate resilient infrastructure and communities to address current and future vulnerabilities. Regarding disaster risk based land use regulation, Strategy 1.3 of Policy 1 of the SAP states that "Guidelines will be developed to integrate land use, land reclamation, coastal alteration, infrastructure development for disaster risk reduction (DRR) and climate change related risk management."[7)]

However, the overcrowding of land use on Male' Island has already made the application of this strategy difficult. In addition, the Land Act 2002 focuses on the use of land by residential dwellings. It provides for the sale / transfer / lease of land and its use for residence, commercial activities, environmental protection and government purposes, but does not directly refer to the use of land for disaster management purposes [8)].

National strategies for disaster risk reduction and climate change adaptation include the National Adaptation Programme of Action (NAPA) in 2006, followed by the Strategic National Action Plan for Disaster Risk Reduction and Climate Change Adaptation (SNAP) 2010-2020[9)]. The Maldives Climate Change Policy Framework (MCCPF 2014-2024) states that climate change measures will be integrated into all relevant sectoral plans. Building climate-resilient infrastructure and communities has been identified as one of the goals. Additionally, a Nationally Determined Contribution for the Maldives (NDC Update (2020)) has been prepared in 2020. NDC outlines the specific implementation of climate change mitigation and adaptation measures.

There is also recognition of the need to strengthen the disaster risk reduction capacity of communities on islands, and to this end the National Community-Based Disaster Risk Reduction (CBDRR) Framework (2014) has been established. Based on this, community-based disaster risk management programmes have been implemented by the respective island authorities, including the development of Disaster Management (DM) Plans and the establishment of Community Emergency Response Teams (CERTs) / DM Units, with the Island Council as the lead agency in each island.[10)11)12)]

In the Maldives, the implementation of climate change adaptation measures with disaster risk management in mind has been promoted through the legal system and strategies. Disaster management in the Male' metropolitan area is also being implemented as part of these national initiatives. A summary of the laws, frameworks and programmes described above is given in the table below.

6) National Disaster Management Authority, n.d., DM Act, https://www.ndmc.gov.mv/policies-and-regulation/rules-and- regulations/

7) Government of Maldives, Strategic Action Plan 2019-2023, https://storage.googleapis.com/presidency.gov.mv/Documents/SAP2019-2023.pdf
8) The Government of Maldives, 2002, Maldivian Land Act (Act No. 1 of 2002), http://extwprlegs1.fao.org/docs/pdf/mdv90854.pdf
9) Republic of Maldives, n.d., Strategic National Action Plan for Disaster Risk Reduction and Climate Change Adaptation 2010-2020, https://www.preventionweb.net/files/60595_maldivesstrategicnationalactionplan.pdf
10) https://ndmc.gov.mv/projects/new-page-2/
11) https://reliefweb.int/sites/reliefweb.int/files/resources/disaster-mgmt-ref-hdbk-Maldives2021.pdf
12) https://ndmc.gov.mv/trainings-and-workshops/cbdrm-training/

Table2-2.1 Laws, frameworks and programs on disaster risk reduction (DRR) and climate change adaptation measures

National Disaster Management Act 2015 [1)]
Disaster Management Act (2015) requires the State not only to respond to disasters but also to mitigate risk, establish emergency response guidelines, ensure disaster preparedness, assist in disaster relief, seek assistance in providing basic necessities, and coordinate all related matters. This act aims to protect people from natural hazards and human-made disasters, incorporate guidelines on disaster risk mitigation and preparedness, reduce disaster risk and adapt a preparatory national strategy, provide assistance in emergency situations, create awareness among the people on DRR and mitigation, etc. 1) National Disaster Management Authority,2015., DM Act, https://www.ndmc.gov.mv/policies-and-regulation/rules-and-regulations/
Strategic Action Plan (SAP)(2019-2023)[2) 3)]
Strategic Action Plan (SAP) 2019-2023 of the Government of Maldives is a central policy framework and planning document that guides the overall development direction of the Maldives for the next five years. The SAP consolidates the current Government's manifesto pledges with existing sectoral priorities. The SAP serves as the main implementation and monitoring tool to track the progress of the delivery of the Government's policies and development priorities. Maldives is highly vulnerable to climate change impact from the geographical and physical characteristics of the islands, including its small size, low elevation, and wide spatial distribution. The capacity of the islands to respond locally to disasters is very low, owing mainly due to the lack of human and technological capacity and high dependency on imported food, fuel and basic commodities. Developing resilient communities would require investment in coastal protection, transition to renewable energy, innovative water filtration and purification systems, and enhancing local human capacity to respond to emergencies. A total of 7 policies and 25 strategies were set by in community resilience sector, as follows: Policy 1: Strengthen adaptation actions and opportunities, and build climate-resilient infrastructure and communities to address current and future vulnerabilities. Policy 2: Promote environmentally sound technologies and practices towards building sustainable climate resilient island communities Policy 3: Foster strategic partnerships and enhance national and international cooperation and advocacy in climate change Policy 4: Enhance island, atoll and city level preparedness, response and recovery capacities to manage recurring hazards Policy 5: Strengthening national level disaster management information, communication and coordination system Policy 6: Ensure and integrate sustainable financing into climate change adaptation opportunities and low emission development measures Policy 7: Strengthen aeronautical meteorology and multi-hazard early warning capacity 2) Government of Maldives,2019, Strategic Action Plan 2019-2023, 3) https://storage.googleapis.com/presidency.gov.mv/Documents/SAP2019-2023.pdf
National Adaptation Program of Action (NAPA)(2006)[4)]
National Adaptation Programme of Action (NAPA) describes the National Adaptation Policy Framework including interactions among climate hazards and risks, exposure and vulnerability of systems, desired sustainable development outcomes, and adaptation strategies, country characteristics, national development goals, and climate hazards and risks specific to the Maldives. The framework adaptation is focused on climate change related hazards, risks, and shocks, and what the Maldives will do to cope with them. 4) Ministry of Environment, Energy and Water, 2006 National Adaptation Program of Action, https://unfccc.int/resource/docs/napa/mdv01.pdf

Maldives Climate Change Policy Framework (MCCPF) 2014-2024 [5)]
Maldives Climate Change Policy Framework (MCCPF) (2014-2024) helps Maldives with the numerous climate change issues. This documents aims to foster and guide national plan of action against current effect of climate change, set out strategic priorities in responses to climate change, promote a coordinated approach among all national stakeholders, and build and strengthen current policies, plans, and institutional structures and incorporate all of these into all related sector plans. The approach to this policy framework is guided by eight principles, i.e. climate leadership, intergenerational equitability, mainstreaming climate change, relevant international commitments, multinational partnerships, transfer of technology, and climate resiliency. 5) Ministry of Environment and Energy, 2015, Maldives Climate Change Policy Framework, https://www.environment.gov.mv/v2/wp-content/files/publications/20150810-pub-maldives-cc-policy-framework-final-10aug2015.pdf
National Community-Based Disaster Risk Reduction (CBDRR) Framework 2014 [6)]
National Community-Based Disaster Risk Reduction (CBDRR) Framework (2014) incorporates plans for institutional arrangements, human capacity, technical capacity, partnerships, and financial resources. Members of National Disaster Management Authority (NDMA), ministries involved in CBDRR, and development partners who supports the Government of Maldives are the primary implementing partners for CBDRR. 6)National Disaster Management Authority, 2014., CBDRM Programs, https://www.ndmc.gov.mv/projects/new-page-2/
Community Based Disaster Risk Management (CBDRM) Program [7)]
Community Based Disaster Risk Management (CBDRM) Programme is conducted by NDMA as an effort to reduce risk and enhance disaster management capacities at the community level. Formulating disaster management plans for each island is a component of the Programme that at least 56 islands have undergone with support from UNDP and UNICEF. By CBDRM activities, the communities identify their vulnerabilities and capacities and work towards enhancing their capacity to create a resilient community. This process also identifies action to be taken by each community member so that each one knows what to do in case of an emergency/disaster. 7) National Disaster Management Authority, n.d., CBDRM Programs, https://ndmc.gov.mv/projects/new-page-2/
Update of Nationally Determined Contribution of Maldives 2020 [8)]
It was prepared by the then Ministry of Environment. It explains what the nation needs to contribute to the measures against climate change. The plan is to reduce greenhouse gas emissions by 26% (or 100% with appropriate international support) by 2030, using 2011 as the base year. Specific measures to achieve this, including the adoption of renewable energy, are outlined. In terms of adaptation, the plan calls for measures to ensure food security, infrastructure resilience, public health, water resources, coastal erosion, storm surge, coral reef protection, weather monitoring / forecasting, and disaster risk reduction (DRR). The budgetary, administrative, and capacity building issues related to climate change that are required for the above are mentioned. 8) http://www.environment.gov.mv/v2/wp-content/files/publications/20181231-pub-ndc-implementation-plan-final-draft.pdf

2-3 Organizational structure and budget of the agencies concerned

2-3-1 Organizational structure and budget

Previous sections discussed the current situation of storm surge, tidal waves and inland flooding in the Male' metropolitan area, which is expected to worsen due to the effects of climate change. In view of assessing the countermeasures against these challenges, this section illustrates the roles of the relevant authorities. The outline of the organizational structure and budget of the agencies concerned are summarized (1) ~ (5) as follow and details are shown in the table below.

(1) Coordinating body

National Disaster Management Authority (NDMA)

Under the National Disaster Management Act, the NDMA is also the implementing agency for disaster risk management at the national level, coordinating disaster risk management activities following the disaster management cycle of preparedness, emergency response, recovery and reconstruction. It reports directly to the President and works under the National Disaster Management Council, chaired by the President.

(2) Implementing agencies

1) Ministry of National Planning, Housing and Infrastructure (MNPHI)

The Ministry of National Planning, Housing and Infrastructure (MNPHI) formulates plans for various projects related to roads,, water supply and sewerage, as well as disaster prevention infrastructure such as rainwater drainage, storm surge / tidal wave protection. After formulating plans, construction and maintenance are managed by Road Development Corporation (RDC) for roads, by State Electric Company (STELCO) for electricity, and by Male Water and Sewerage Company (MWSC) for water supply and sewerage. It is also responsible for the maintenance of the seawalls on the island of Male', with which Japan has cooperated in the past. It is the coordinating body for the World Bank's Urban Development and Resilience Project.

2) Housing Development Corporation (HDC)

The Housing Development Corporation (HDC) was established in 2001 as a 100% government owned corporation. It is responsible for the development of Hulhumale Island. HDC is responsible for the planning and construction of seawalls and stormwater drainage on Hulhumale Island. It is a self-financing corporation. The development of the southern part of Hulhumale Island (Phase I) was funded by the government, while the development of the northern part of the island (Phase II), including the construction of infrastructure, has been funded by proceeds from the lease / sale of buildings / land.

3) Male' Water and Sewerage Company (MWSC)

MWSC constructs and operates rainwater / sewage drainage and water supply facilities in the metropolitan area under the plans drawn up by MNPHI. In Male', MWSC operates 15 rainwater drainage pumping stations.

4) Maldives Land and Survey Authority (MLSA)

MLSA is responsible for producing a map of the whole of the Maldives, including the Male' metropolitan area. On the other hand, a digital elevation map with the accuracy required for rainwater drainage in the metropolitan area has not been produced.

5) Male' City Council (MCC)

The City Council of Male' is responsible for the registration of households, the management of municipal schools and maintenance of road drainage. Currently, the Streetscaping Project, funded by the MCC, is ongoing to improve the city's roads and gutters.

(3) Disaster prevention administration and disaster information

Maldives Meteorological Service (MMS)

Meteorological observations are carried out at 40 automatic meteorological stations throughout the country and warnings of weather-related disasters are issued. Warning is based on three levels, depending on the magnitude of the event: rainfall, tides, waves, cyclones, etc. It has a research unit on climate change. It is under the jurisdiction of the MECCT.

(4) Environmental administration

Ministry of Environment, Climate Change and Technology (MECCT)

The Ministry of Environment, Climate Change and Technology (MECCT) is the lead agency for

government policy and administration related to wastewater, renewable energy and the environment. It coordinates the actions to achieve the Sustainable Development Goals (SDGs) within the government. Recently, a new Climate Change Department has been established. It prepared the MCCPF (2014-2024).

(5) DRR education, research and human resource development

1) Ministry of Education (MOE)

There are 17 schools on Male' Island under the jurisdiction of the Ministry of Education, and five schools are currently under construction on Hulhumale Island. At this moment, there is no school curriculum for DRR education or teachers guideline for such purpose. There is an emergency operation plan for fires, but not for inland flooding, storm surges nor tsunamis.

2) Maldives National University (MNU)

MNU is the only university in Maldives with a Department of Civil Engineering in the Faculty of Engineering. The department's curriculum includes basic subjects such as hydrology, hydraulics and coastal engineering, but does not include applied subjects such as urban drainage and design practice.

Table2-3.1 Organizational structure related to disaster prevention

Ministry of National Planning, Housing and Infrastructure (MNPHI)
1) Organization [1)] MNPHI formulates national plans for land development, including urban and island development, and regulates construction projects and land use. MNPHI is responsible for housing and infrastructure projects, including urban development, roads, water supply, sewerage, storm water drainage, coastal protection and electricity. It supervises HDC, MWSC, RDC and MLSA. 2)Budget Project expenditure in 2019, 2020 and 2021 was US$115 million, US$203 million and US$345 million (around ¥39.7 billion or ¥74,000/person) respectively. [2)] ※)  3) Projects related to disaster prevention MNPHI is the coordinating body of the Steering Committee of the World Bank's Urban Development and Resilience Project.[1)] 4) Issues and observations For water and sewerage, MNPHI is responsible for planning and MWSC for construction and maintenance. Staff have limited expertise in urban drainage and storm surge protection with little experience to design such facilities. This is likely to lead to low capacity of maintenance. The educational content at MNU is insufficient in this area, making it difficult to recruit technical staff with the necessary skills. ※) In Japan, the Ministry of Land, Infrastructure, Transport and Tourism's budget for 2021 was 2,493.3 billion yen (20,000 yen/person)[3)] and the Tokyo Metropolitan Government's Construction Bureau's was 568.9 billion yen (47,000 yen/person)[4)] 1) Ministry of National Planning, Housing and Infrastructure, n.d., https://planning.gov.mv/cidd 2) National Budget 2021 of Maldives, n.d., https://budget.gov.mv/en/office-expenditure/total/48 3) https://www.mlit.go.jp/common/001396485.pdf 4) https://www.kensetsu.metro.tokyo.lg.jp/about/yosan_kessan/index.htm

Housing Development Corporation (HDC)

1) Organization [1] [2]

The company was established in 2001 by a presidential decree and is 100% government-owned, under the supervision of the Ministry of Finance. HDC has developed a land use plan for Hulhumale Island and is implementing land reclamation, housing construction, and infrastructure development. Since 2009 it has also been responsible for the development of the islands of Gulhifalhu and Thilafushi. It plays an important role in the development of housing, industry and commerce in the capital region.

2)Budget

HDC is a self-financing organization and currently receives no funding from the government. Phase I was funded by the government and Phase II was funded by the lease and sale of buildings and land.

3)Projects related to disaster prevention

The total development area for Phase I is 188 ha and for Phase II is 214 ha, for a total of 403 ha. HDC is responsible for the planning, construction, and maintenance of the seawall on Hulhumale Island. Currently, a water resource development plan using rainwater drainage is under planning.

4)Issues

- In the development of Hulhumale Island, although this is not currently a problem, the increase in urbanization may cause difficulties in drainage as the ground surface is covered with pavement and buildings, and as open space is lost and the function of watershed storage / infiltration is lost.
- There is a risk that climate change will cause sea levels to rise, leading to more frequent damage from storm surges and tidal waves. There is also concern that increased rainfall intensity will make urban drainage more difficult.
- There are staff members with general knowledge of architecture, urban planning, and in civil engineering. However, there are no staff members with expertise in urban drainage nor coastal protection. In the Maldives, the education system does not accommodate students with training in such practical expertise, and engineers with such practical expertise are not experienced in these fields. There are difficulties in recruiting engineers of these fields by the agencies. In practice, this situation is being addressed by outsourcing to consultants.

1) https://hdc.com.mv/about/
2) https://hdc.com.mv/app/files/2021/05/210517_HDC_Investor%20Presentation.pdf

Male' Water and Sewerage Company (MWSC)

1) Organization [1][2]

Source: MWSC HP

・MWSC was established in 1995. It is supervised by the MNPHI. It is responsible for the construction, maintenance and operation of water, wastewater and stormwater drainage facilities in the Male' metropolitan area. It owns and operates desalination plants on the islands of Male' and Hulhumale. The company also conducts water and sewage pumping systems for high-rise buildings in some areas, electrical installations and waste management.

In the area of rainwater drainage, the company maintains and operates the drainage pumps and the connecting pipes. The MCC (Male' City Council) and the RDC (Road Development Corporation) are responsible for the construction and maintenance of road drains. It should be noted that there are no sewage treatment plants in the metropolitan area, and plans are currently underway to build those on the islands of Male' and Hulhumale under the World Bank's Urban Development and

Resilience Project. The company has professional and technical employees in the fields of civil engineering, electrical engineering, environmental engineering, mechanical engineering, chemical engineering and architecture. The company is owned by the Government of Maldives (80%) and Hitachi Ltd (20%).[3)]

2) Budget

The facilities are maintained and operated by water and sewage collection charges.

3) Projects related to disaster prevention

Under the Urban Development and Resilience Project of the World Bank, the construction of a storm water drainage and storage facility on the island of Male' is in progress. The selection of a consultant for the detailed design of the facility is in the process (as of Dec. 2021). Once completed, the project will be managed and operated by MWSC.

4) Issues

- The fifteen rainwater drainage pumping stations on the island of Male are manually operated, and lack efficiency without investment in systemic and synchronized operations.
- When considering increasing the capacity of rainwater drainage on roads, there is no room for road space and drains cannot be extended.
- Residents are connecting storm water drainage to the sewer without permission. The process of dealing with this is time-consuming and has not been completely eliminated.
- Inter-organizational cooperation between the relevant agencies (MWSC, MCC, RDC) on rainwater drainage is to be encouraged

1) https://www.mwsc.com.mv/CompanyOverview
2) https://www.mwsc.com.mv/
3) MWSC Annual report 2020, p7

Maldives Land and Survey Authority (MLSA)

1) Organization [1)2)]

The MLSA, under the administration of the MNPHI, was established in 2011 to integrate land information management and research. It has the authority to develop, manage and regulate land cadastral surveys, mapping and the national geographic information system. It is composed of four departments: Land Management, Survey Regulation, National Mapping and National GIS.

2) Issues

- Although drone surveying has been carried out, the city of Male' is densely built up and the frequent redevelopment and construction of structures interferes accurate mapping. Densely built structures make it difficult to carry out aerial surface surveying using drones.
- The Digital Elevation Model (DEM), as described by MLSA is actually DSM (Digital Surface Model: the height of the ground surface includes the height of trees and human-made structures). This model cannot be used for planning drainage systems.
- At this stage, topographic maps of the islands of Male' and Hulhumalé are not available and the MLSA has no plans to produce them at the moment. The budget shortfalls seems to have led to this situation.

1)https://presidency.gov.mv/Home/
2)https://www.mlsa.gov.mv/index.php

Ministry of Environment, Climate Change and Technology (MECCT)

1) Organization [1)]

MECCT is responsible for water hygiene, clean energy, waste, pollution, coastal erosion, natural environment and climate change. It coordinates the actions towards achieving the Sustainable Development Goals (SDGs) within the government.

It is composed of six departments: Climate Change, Energy, Environment, Water and Sanitation, Waste Management and Pollution Control, and Corporate Management. The ministry supervises six organizations such as Maldives Meteorological Service, the National Center for Information Technology and the Communication Authority of Maldives.

2)Program and framework related to DRR
National Adaptation Programme of Action (NAPA 2006) and Maldives Climate Change Policy Framework (MCCPF 2014-2024) are underway.
3)Projects related to disaster prevention
With the support of the Asian Development Bank (ADB), a hazard map of climate-related disasters has been prepared (Appendix 1).
4)Issues

- Waste management, soil/beach erosion and climate change, and research on climate change are major challenges (Appendix 2).
- The ADB-supported hazard maps provide the spatial information needed to assess future development investments, but they have not been produced with the accuracy required for use in evacuation operations. Detailed maps are needed for district-by-district inundation and storm surge in the metropolitan area.
- There is a shortage of technical staff.

1) Ministry of Environment, Climate Change and Technology, n.d., https://www.environment.gov.mv/v2/en/

Maldives Meteorological Service (MMS)

1) Organization[1)]
Under the MECCT, it carries out meteorological observations, seismic observations and weather forecasting and warning. It also conducts research on climate change. It is composed of three departments, Weather Service Division, Climate Service Division and Meteorological Administration Division. Observations and forecasts are carried out 24 hours a day, 365 days a year at the main office in Hulhule and at four branch offices on the islands. The meteorological stations under their jurisdiction and the equipment used are listed in the table below. 25 of the 40 automatic meteorological stations have been set up with the support of Italy. The meteorological stations are evenly distributed throughout the country. MMS is staffed with 105 employees. The Weather Service Division is operated in 24-hour shifts with 4 to 5 staff per shift.
Observations include rainfall, temperature, barometric pressure, wind speed, wind direction, tide level, wave height and direction, cloud / rain radar observations, earthquakes. There are no observatory stations in the metropolitan area for wave height and direction.

2) Issues

- As of March 2021, only one person has been assigned to the climate change research department. There is a shortage of research staff.
- There is only one meteorological radar on Male' Island in the whole of the Maldives, which does not cover the country. In order to cover the whole country, two or more radars are required.
- Only 25 of the Automatic Weather Stations (AWS) are in operation. It is difficult to maintain these on remote islands with a shortage of personnel. Training of maintenance personnel is being carried out.
- Waves from the open sea may cause disasters in the future due to climate change, so it is necessary to observe wave height and direction. However, there is no observation equipment / facility for the purpose at this moment.

Meteorological stations and equipment of the MMS

Meteorological stations and equipment	Number
Manual meteorological station	5
Automatic weather station	40
Upper Atmosphere Observatory	1
Meteorological radar	1
Tide gauge	3
Satellite Image Receiving System	1
Numerical Weather Prediction Model	1

1) Maldives Meteorological Service, n.d., https://www.meteorology.gov.mv/about-us

National Disaster Management Authority (NDMA)

1） Organization [1)]

・It is under the National Disaster Management Council headed by the President.
・In collaboration with government agencies, atoll/island authorities, the private sector, and non-governmental organizations, it conducts disaster management in the national level, in terms of preparedness, emergency response, recovery and reconstruction.
・It consists of four departments: Policy and Planning (1 member); Program, Research and Advocacy (3 members); Emergency Management (3 members); and Corporate Affairs (10 members). There are total 20 staff.

2)Budget [2)]

Expenditure in 2021 was 871,000 USD (About 100 million yen) ※)

3)Emergency response in the event of a disaster (Appendix 3)

・To publicise disaster warnings communicated by the MMS to the public and to coordinate disaster response activities by the relevant agencies.
・In the event of a disaster, the NDMA, under the direction of the National Disaster Management Council (NDMC) with the President as the chair, and, receiving the technical advice from the National Disaster Steering Committee (NDSC), coordinates all disaster response activities at the National Emergency Operation Center. The NDMA coordinates with all the relevant disaster related organizations. NDSC members comprise of senior technical representatives from all stakeholders.
・In the Maldives, there are 20 atoll municipalities and 3 city councils for 186 inhabited islands. They are expected to respond promptly to emergencies in their respective jurisdictions.
・As one of these municipalities, Male' is managing the disaster under the direct support and coordination of the NDMA.

4)Projects in progress

・CBDRM programme: With the support of UNDP and UNICEF, a CBDRM programme is being promoted to strengthen the capacity of local communities as the actual actors in disaster management. The programme is being implemented and training is provided to the community emergency response teams established on the islands (see Table 2.2.1 above). Other international support to the NDMA is summarised in Table 2.3.2.
・School Program: Disaster education and evacuation drills for teachers and students were conducted in 9 schools from 2013 to 2016.[3)]

5)Challenges

The interview with Director of Emergency Management of NDMA provided insight into challenges the institution face in promoting DRR.

・There is a shortage of staff for disaster management and currently 20 staff are working for the whole of the Maldives. There are only 10 technical staff. In the event of a disaster in Male', all 20 staff will respond to the disaster. In the event of a disaster in a remote island, the military is in charge of the response, but the response has not been sufficient due to the delay in the arrival of the rescue team.
・The densely built-up nature of the Male' island makes it difficult to regulate land use for disaster prevention. To regulate building-to-land ratio and floor-area ratio is also difficult. The challenge is to develop an urban plan that takes DRR into account and to implement it from a long-term perspective.
・It is possible to determine the approximate location of inland flooding from experience, but there are no hazard maps showing the inundation area and evacuation route / facilities.
・There is a lack of DRR education in schools and awareness among the general public. There is no curriculum on practical DRR management in universities in the Maldives.

・Both the public and politicians lack awareness of disaster management and do not necessarily see the link between climate change and disasters.
・In this context, the NDMA has been tasked with the task of raising awareness of DRR in society.

※)According to the Cabinet Office, Japan's proposed budget for disaster prevention for 2021 is 7.2 billion yen.
1)National Disaster Management Authority, n.d., https://www.ndmc.gov.mv/about/divisions/
2)National Budget 2021 of Maldives, n.d., https://budget.gov.mv/en/office-expenditure/total
3)https://ndmc.gov.mv/projects/school-program/

Ministry of Education(MoE)

1)Organization
MOE is responsible for all national primary, secondary and high schools in the Maldives. It does not have jurisdiction over public schools and community schools. The Ministry is located on the 8th and 9th floors of the joint government building.
2)Challenges
・Education on DRR and climate change have not been carried out in the school curriculum. School teachers are not knowledgeable enough about DRR. The improvement of this situation is a challenge.
・In terms of disaster prevention in school buildings, the building regulations stipulate the structure of the building, but do not include any measures against disasters or future climate change. There are no adequate measures in place for fire prevention. There is a need for both structural and non-structural measures against disasters.

Maldives National University (MNU)

1)Organization
MNU is the university with 11 faculties/schools/centers. 75% of its budget comes from the government, but it is an independent university corporation. It has a semester system, with the first semester February to mid-June and the second semester August to mid-December.
2)Challenges
・The Department of Civil Engineering at MNU offers lectures in basic subjects related to DRR infrastructure, but it is in want of courses on practical aspect (Appendix4).
・The DRR course in the Department of Civil Engineering supported by the EU is currently being planned and a draft syllabus is available.
・There is no record / archive of the government activities in disaster management.

Maldives National Defense Force(MNDF)

1) Organization[1)]
In addition to military functions, the MNDF is also responsible for fire and rescue services. In 2015 and 2016, Japanese grant aid provided a total of 1.1 billion yen of equipment for disaster risk management (drainage pumps, cranes, etc.), contributing to the improvement of MNDF capacity on disaster risk management.[2)]
2) Challenges
When a disaster occurs on a remote island, it sometimes takes a long time to arrive at the site. Shortening the travel time is an issue.

1)Maldives National Defence Force(MNDF), https://mndf.gov.mv/mndf/index.php
2)https://www.mofa.go.jp/mofaj/gaiko/oda/data/gaiyou/odaproject/asia/maldives/contents_01.html#2701

Male' City Council (MCC)[1)2)]
1） Organization Under the mayor, deputy mayor and 10 councillors, 127 staff are working. It consist of Council bureau, Admin and front office, Financial management, Procurement, Information communication technology, Human resources management and development, Land and building, Family registration, Asset management section, Religious, and Villingili section. The mayor and councillors are elected by the public. Their works are registering households, granting building permits, cleaning roads and parks, installing and maintaining streetlights / traffic lights, cleaning and maintaining road drains, collecting and disposing of waste, running municipal schools, and maintaining sanitation in the city. 2)Projects related to disaster prevention currently underway The city's roads are being improved with the Streetscaping project. The Streetscaping project is funded by the municipal budget and is being carried out by the Road Development Corporation. 1)https://Male'city.gov.mv/about-us/ 2)Male' City Council, Annual Report 2020

2-3-2 International cooperation

While the organizational structure is in place as explained above, the country is dependent on foreign assistance due to insufficient funding for policy implementation and a lack of human resources with expertise. UN agencies have contributed to capacity building and the provision of financial resources. The World Bank's Urban Development and Resilience Project is providing financial and technical assistance for the development of facilities and strengthening of institutional capacity for storm water drainage, sewage treatment and DRR management in the Male' metropolitan area. In addition to the UN and international organizations, bilateral cooperation has been extended from various countries. Japan has provided financial assistance in the past for coastal protection. Japan is currently implementing a project on technology transfer and human resource development in the field of coastal management and disaster information dissemination. The table below gives an overview of these foreign assistance.

Table 2-3.2 International cooperation to Maldives in Disaster Risk Reduction[13)]

United Nations agencies	
UNICEF	UNICEF supports the establishment of Community Emergency Response Teams (CERTs) on atolls and islands and provides equipment such as drainage pumps.
UNDP	With a focus on climate change adaptation, UNDP supports the Ministry of Environment through the Green Climate Fund. It also supports community-based DRR and local disaster / climate risk management plans.
Other international organizations	
South Asian Association for Regional Cooperation Disaster Management Center	Maldives is a member country of the South Asian Association for Regional Cooperation (SAARC) Disaster Management Center (DMC), established in November 2016. The DMC supports member countries' disaster risk reduction initiatives through scientific and technical knowledge, information exchange, capacity building, joint research and networking.
World Bank	Urban development and resilience project is being implemented.
ADB	Multi-hazard Risk Atlas of the Maldives was produced in 2020 (Appendix 1).

By-lateral cooperation	
Japan	It has a long track record of cooperation in areas related to DRR and climate change adaptation, including the Male Island seawalls. The table below shows some of the projects currently being implemented.
USA[1)]	USA supports economic resilience, democratic governance, sustainable environment, capacity building in marine management, monitoring natural disasters and adaptation to its impact 1) USAID, n.d., Maldives – Environment and Global Climate Change, https://www.usaid.gov/maldives/environment-and-global-climate-change
Italy	Financial support to MMS for the establishment of 25 automatic weather observatories.
International support for the NDMA	
NDMA has received funding support from a number of international organizations; UNDP, UNICEF, UNISDR, Asian Disaster Preparedness Centre (ADPC). It also receives technical cooperation from the South Asian Association for Regional Cooperation (SAARC), United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) and Asian Disaster Reduction Centre (ADRC).	

13) Center for Excellence in Disaster Management & Humanitarian Assistance, 2021, Maldives Disaster Management Reference Handbook, https://reliefweb.int/sites/reliefweb.int/files/resources/disaster-mgmt-ref-hdbk-Maldives2021.pdf

Table 2-3.3 JICA's projects related with DRR currently implemented

Project for the Digital Terrestrial Television Broadcasting Network Development (Grant Aid, G/A on May 30th, 2.792 Bil.Yen)
Of the four commercial and public broadcasters in Maldives, only the public corporation broadcasts in the national level. There is a need to improve access to information so that the programmes of the commercial broadcasters can be viewed / listened to in the local islands. There is also an urgent need to improve the broadcast infrastructure for the rapid provision of disaster information. This cooperation aims betterment of access to information for people with the development of a terrestrial digital television broadcasting network using the Japanese system, contributing to improvement of the information gap among islands, as adaptation measures against climate change and disaster risks. https://www.jica.go.jp/oda/project/1660390/index.html
Digital Terrestrial Television Broadcasting Operation Capacity Improvement Project (Technical Cooperation, 2019-2025)
This is the project for technology transfer for the operation of the above-mentioned system. The project is to strengthen the capacity of digital terrestrial TV broadcasting, equipment operation, program production and operation of EWBS. This will contribute to the proper operation of the digital terrestrial TV broadcasting network and to the correction of information gaps between islands, in terms of weather and DRR information. https://www.jica.go.jp/oda/project/1503035/index.html
Project for Safe and Resilient Islands against Climate Change and Disaster(2021~2025)
This is a technical cooperation project that contributes to develop the coastal conservation and management system in Maldives. The goal of the project is to strengthen the capacity of relevant agency staff to implement coastal conservation measures taking into account the climate change impacts. The main counterpart organization is MECCT. On the islands for the pilot activities, the project will develop plans for integrated coastal management, establish a coastal management system, and collect / share basic data on climate change. This project and the projects on Digital Terrestrial Television Broadcasting are part of a program approved and endorsed by the Green Climate Fund. https://www.jica.go.jp/press/2021/20210702_31.html

2-4 Storm Surge and Inland Flood Control Projects in Male' Metropolitan Area

Ongoing projects related to storm surge and inland flooding in the Male' metropolitan area are as follows. The details are shown in the table below.

(1) Hulhumale Island Development (HDC)
(2) Urban Development and Resilience Project (World Bank)
(3) Streetscaping Project (Male' City Council)

Table 2-4.1 Ongoing projects related to storm surge and inland flooding in Male' metropolitan Area

1)Hulhumale Island Development Project[1) 2)]

The development of Hulhumale Island is being carried out by the Housing Development Corporation (HDC). The official name of the development is Hulhumale Development.

Details

The capital island of Male' has an area of 1.8 km^2 with no room for expansion. In the 1990s, Male's population increased due to the concentration of people from remote islands seeking jobs and education in the capital. To solve this problem, the plan to build a new city on an artificial island was developed and has been implemented. The development of Hulhumale between 1997 and 2001 was led by the Hulhumale Development Unit of the President's Office. In 2001, HDC was established with 100% government funding.

Progress

Construction work started in 1997 and the first phase of 1.88km^2 was completed in 2002. 2.14km^2 of the second phase, totaling 4.03km^2, was reclaimed in 2015.[1)] As sea level is expected to rise in the future due to climate change, the elevation of the first phase area was set at 1.8m and that of the second phase at 2m. A connecting bridge from Male' to Hulhumalé was completed in 2018 with Chinese funding. The three islands of Male', Hulhule and Hulhumale Islands have been connected by the bridge and a causeway. About 50,000 people are living on Hulhumale Island[3) 4)]. The second phase of the project includes residential area, commercial / financial areas, an IT park, a convention centre and green parks.

Current situation

At present, stormwater drainage facilities have not been provided because the rate of runoff is still low. This is because there is enough green/open space for stormwater to infiltrate. The open space of 2m^2/person has been reserved to retain stormwater. However, if development progresses, drainage facilities will be required.

As for the seawalls on the coast facing the open sea, large rubble stone seawalls have been constructed on the north coast. The east coast was deemed stable by the HDC, and in some parts temporary measures using cement bags have been placed to decrease the impact of erosion.

Before development (1997)

Development in progress (2018)

View of Phase II across the canal from the side of the Phase 1 area

Urban area in Phase I

1) HDC Annual Report, 2019, p.9
2) HDC Company presentation, May 2021
3) https://www3.nhk.or.jp/news/html/20211109/k10013338581000.html, 2021 年 11 月 9 日
4) Norman Miller (2020-09-10). "A new island of hope rising from the Indian Ocean". BBC Travel.、2020 年 9 月 10 日

2)World Bank "Urban Development and Resilience Project". [1) 2)]

With the aim of modernising the urban infrastructure and increasing its resilience to climatic hazards, the project is being implemented from May 2020 to June 2026 with funding of USD 16.5 million (approx. JPY 1.8 billion). The proportion of grant and loan is 50% each.

Robust infrastructure and emergency response

a. Construction of sewage treatment facilities on Hulhumale and Male' islands
b. Construction of drainage and underground rainwater storage tank on Male' Island > Preparation of consultant selection for planning and design of facilities
c. Establishment of an Emergency Operation Coordination Center (EOCC) > Site selection underway, facility and equipment plans being developed
d. Strengthening of the fire and rescue services on Male' Island>The implementation plan is being discussed with the NDMA.

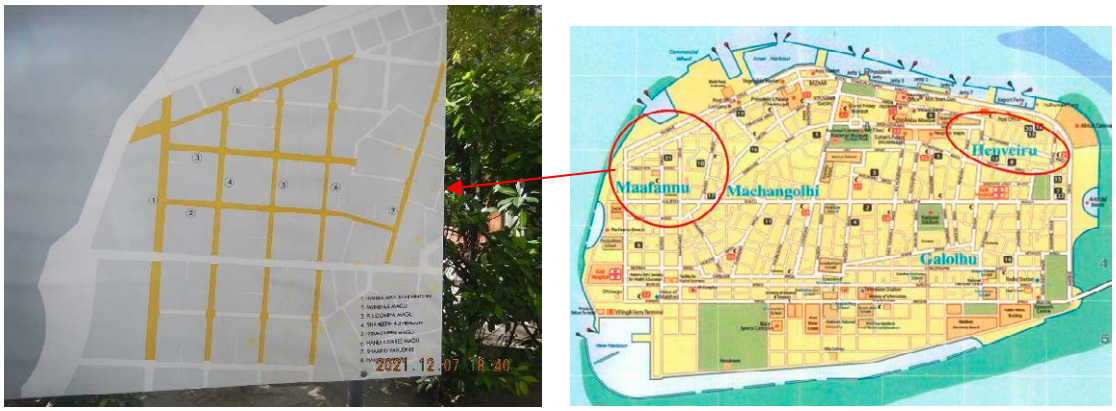
Sustainable urban development

a. Research on sustainable urban infrastructure and services: analysis and feasibility studies of urban infrastructure and services, including local development, affordable housing development and financing options.
b. Strengthening of building code enforcement mechanisms: development of building permit procedures, online building approval systems, and capacity building programmes for officials responsible for building permits / operations.

1) World Bank, 2020, Maldives to Improve Resilience through Urban Development, https://www.worldbank.org/en/news/press-release/2020/04/30/maldives-improves-resilience-urban-development
2) World Bank, 2021, Maldives Urban Development and Resilience Project, https://projects.worldbank.org/en/projects-operations/project-detail/P163957

3)Streetscaping Project[1) 2)]

This is a project for the maintenance and beautification of roads in Male', including stormwater drains, water and sewage pipes, buried electric cables, planting, lighting, and sidewalks.
The project is planned by MNPHI and is currently under construction by MCC contracted to the Road Development Corporation. The project was inaugurated in January 2020 and will last for two years. 18.8 km of the city's roads will be covered, at the cost of 50.96 million MVR (3.75 million yen) [3)]. Construction work started in April 2021 on 1.97 km of 13 streets in the northern district of Henveiru. As of December 2021, work is also underway on 8 streets of 1.9 km in Maafannu District.



Project area (circled in red on the right) as of December 2021

Information boards about the project placed in the Maafannu District

The road in the Maafannu District after construction

1)https://rdc.com.mv/projects/Male'-streetscaping-project-segment-i 15 July 2021
2)https://psmnews.mv/en/90728 Aug 17, 2021
3) Average conversion rate in December 2021: ¥113.88/USD, ¥7.35/MVR

2-5 Challenges on Countermeasures against Climate-Related Disasters in the Male' Region

The figure below shows the problem analysis on the climate-related disasters in Male' region. The red boxes in the figure are the measures that are considered to solve the causal problem and lead the situation to the desired direction.

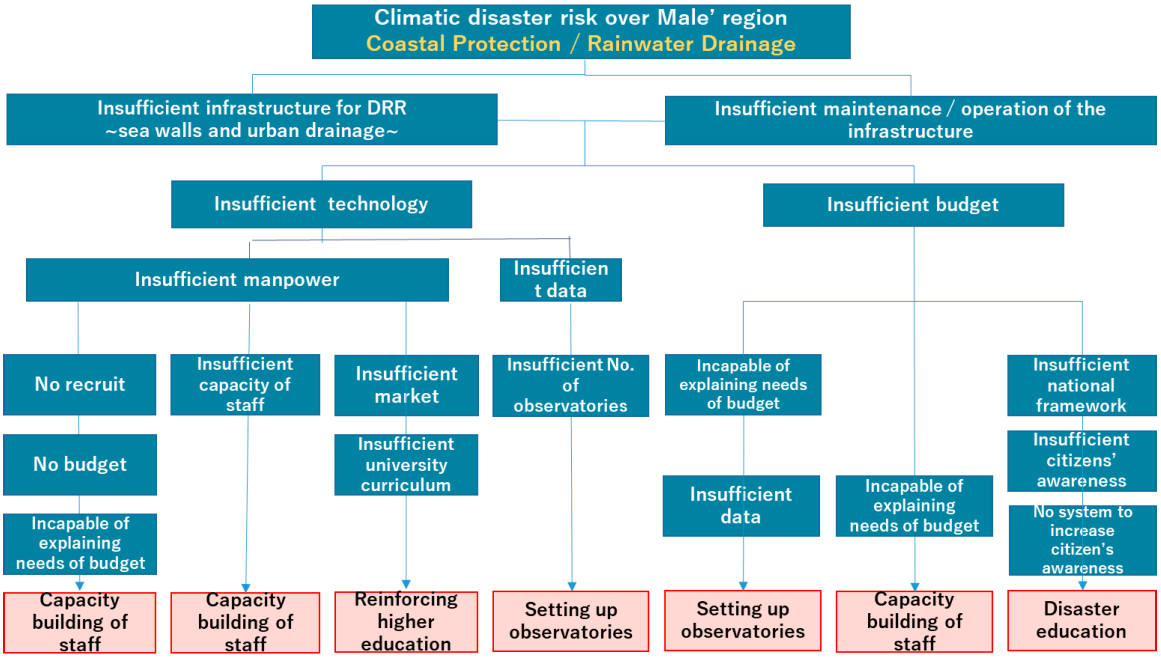


Figure 2-5.1 Problem analysis on the climate-related disasters in Male' region

The number of technical staff of MNPHI, HDC and other agencies who plan, construct and maintain the DRR facilities are not enough to deal with the work quantity considering the increasing disaster risks in the area. Also, promoting disaster prevention education is important for reducing the risk of climate-related disasters in the Male' region because it will increase awareness among the public about the importance of DRR policies. These two points are discussed below.

1） Shortage of human resources

There is a shortage of staff with expertise in MNPHI, HDC, and other agencies described above. All of the technical staff interviewed in this survey have obtained their degrees abroad, and their technical expertise may not be enough to address issues of storm surge, coastal erosion, and urban drainage.

In order to cope with disasters that are expected to become more severe due to climate change in the future, as a long-term solution, it is recommended to strengthen the expertise of incoming staff by incorporating studies of practical aspect of DRR in the higher education in the Maldives, especially at MNU, so that there will be a larger pool of candidates with advanced knowledge in DRR. It is also necessary to enhance the practical capabilities of existing staff in the relevant agencies.

2) DRR education in school

The capability of drainage facilities in Male' is below the current flood magnitude, and there are areas of the seawall around Male' Island that need to be reinforced. In order to cope with this situation, i.e., to properly maintain and improve DRR infrastructure, a reasonable amount of funds and human resources are required. For this purpose, the importance of DRR needs to be widely understood in the society and in the political levels, but it is observed that this is not currently the case. One of the long-term solutions to this problem is to incorporate DRR education into school curriculum. This will not only have a direct effect on students, but will also enable them to pass on their knowledge to their parents and the surrounding community, which in turn will raise awareness of DRR in society as a whole and influence policy and administration.

Chapter3 Climate-Related Disasters and the State of Infrastructure in the Male' Region

In this chapter, the current situation is clarified for the following.

(1)Development of disaster prevention infrastructure for storm surge, tidal waves, and inland flooding, which are dominant disaster risks in the Male' metropolitan area.

(2) Shortage of human resources identified in Chapter 2, and promotion of disaster education.

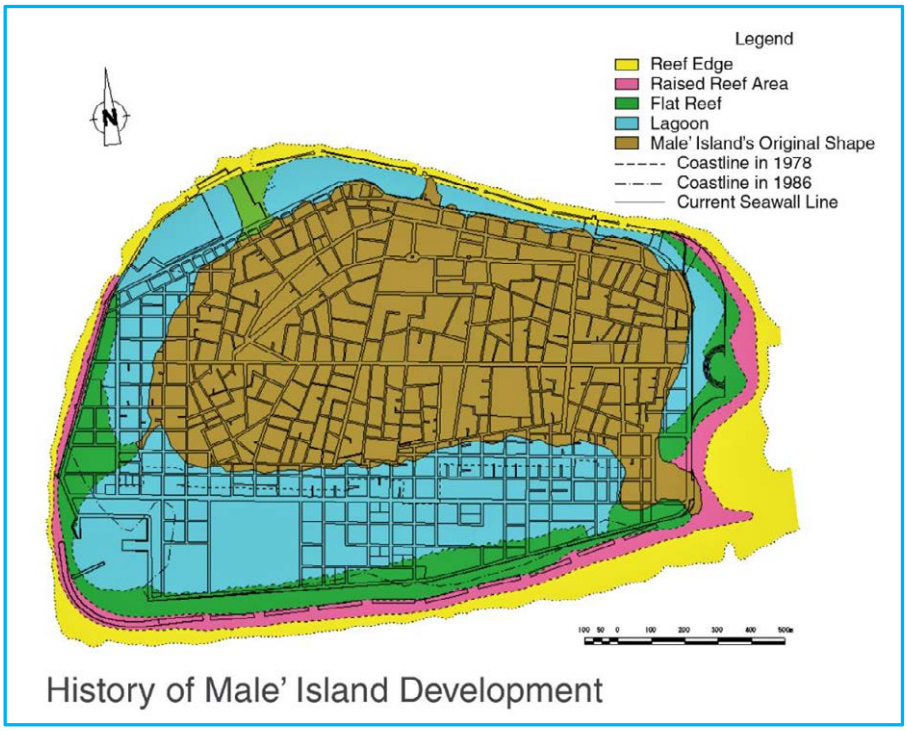
(3) Operation of lifeline infrastructure such as electricity and water supply, and public facilities such as schools and hospitals, in the event of damage due to climate-related disasters.

3-1 Storm Surge

3-1-1 Natural conditions

(1) Topography and coastal deformation

Male', as the capital of the Maldives, is the center of politics, economy, commerce, education, and medical care. As a result, the influx of population from the local islands has been remarkable, and the island has been reclaimed and widened by about 60 hectares of the surrounding reefs since 1979 as shown in Fig.3.1.1, reaching about 180 hectares in 1986. Later, when the seawall on the east coast of Male' Island and the seawall on the south coast were constructed, about 3.7 hectares of land was reclaimed. In addition, in order to cope with further population growth, Hulhumale Island has been reclaimed in two phases (Phase I: approximately 188 hectares, Phase II: approximately 240 hectares) as a residential and commercial area since 1997 in order to utilize the vast reef adjacent to Hulhule Island, which is home to the Velana International Airport. In 2018, the bridge connecting Male' and Hulhumale Island was completed, and a circulating bus service operates between the two islands, forming the Male' metropolitan area.[5)]



Source: 1992 JICA Study Report

Figure 3-1.1 History of Male' Island Development

5) As of the writing of this report (March 2022), three bridges are planned to be constructed to connect the island of Male' with the islands of Villingili, Gulhifalhu, and Thilafushi, located to the west of Male', and are scheduled for completion in April 2024.

Source: 1992 JICA Study Report

Figure 3-1.2 Aerial Photo of Male' in 1992 and 2020

Source: Google Earth, HDC Homepage

Figure 3-1.3 History of Hulhumale Island Development (1997, 2012 and 2021)

(2) Tide, wave height and weather data

The most recent wave height and tide data for Male' Island is from the Development Study Report on the Seawall Construction Project for Male' Island conducted in 1992 by JICA. According to this survey, the lowest tide level was +0.00m, the mean water level was +0.64m, and the highest tide level was +1.34m. In 1987, swells originating in the southern Indian Ocean recorded wave heights of up to 3 m off the east and south coasts of Male' Island (Source: 1992 JICA Report). The tide level, wave height, seawall top height and seawall length in the JICA survey in 1992 are summarized in Table 3.1. In terms of wind direction, the prevailing winds are from the northeast to east-northeast in December-February, irregular in March-April, west-southwest to west-northwest in May-June, northwest to west in July-October, and west in November. The wind speed can exceed 15 m/s in the west and east-northeast seasons, but is usually not that high. Wave direction matches the wind direction as wind waves, but swell from the south is generated.

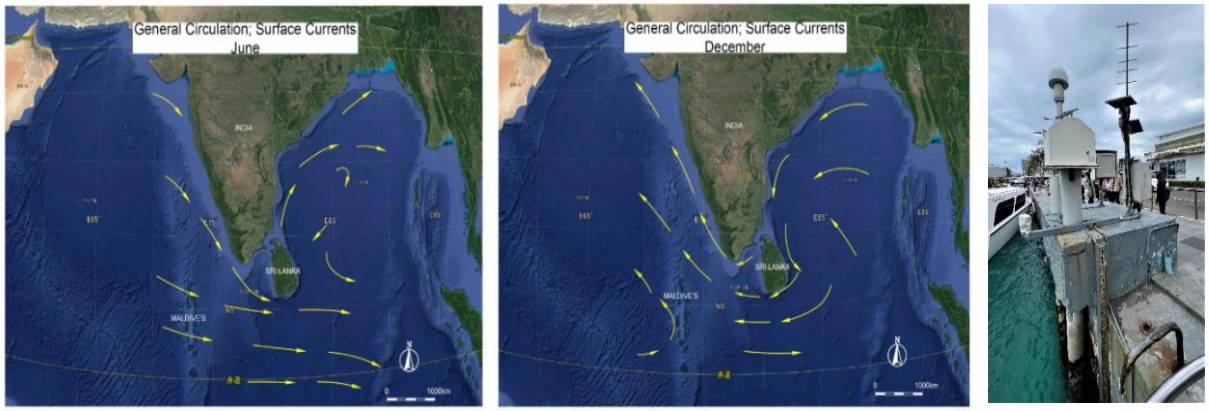
Table 3-1.1 Condition of Wave and Tide

Wave & Tide Condition and Top Level & Length of Seawalls						
Location (Coast)	Offshore Wave Height (m)	Wave Period (sec)	Design Wave Height (m)	Design Tide Level **(m)	Top Level** of Seawall (m)	Length of Seawall (m)
East	3.0	16.0	1.3	1.64*	2.80 - 3.20	1,266
South	3.0	16.0	0.7	1.64*	2.10 - 2.50	1,508
West	1.2	4.6	1.2	1.34	2.60 - 3.00	774
North	0.6	4.6	0.6	1.34	2.10 - 2.30	1,441
* Tide considered wave set up				** Above Lowest Water Level (+0.00 m)		

Source: 1992 Survey on the Planning of Coastal Disaster Prevention Facilities on the Island of Male'

(3) Currents

According to the JICA Survey in 1992, westward currents prevail from December to April, and eastward currents prevail from May to August, as shown in Fig.3.1.4. Although tide gauges have been installed as described in (4) below, wave and current observations were conducted during the JICA survey in 1992, but not on a regular basis due to the difficulty in maintaining them.



Source: The report of "The Development Study on the Seawall Construction Project for Male' Island" (JICA), December 1992 (L), JICA Study Team (R)

Figure 3-1.4 Surface Current and Tide Gauge

(4) Tide level observation

After the 2004 tsunami, the University of Hawaii installed a tide gauge at the seawall of the Velana International Airport (see Fig.3.1.4), and the tide level data is instantly transmitted to the University of Hawaii and also instantly shared with the Maldives Meteorological Service of the MECCT located at the same airport

3-1-2 Overview of the disaster

(1) Floods caused by high waves in 1987 and 1988

Prior to 1986, there was no record of storm surge damage in Male' Island, but in April 1987, June 1988 and September 1988, storm surges hit Male' Island, causing economic losses of about 5 million USD. The wave height off the coast of Male' Island at that time was estimated to be 3.0 m[6)7)].

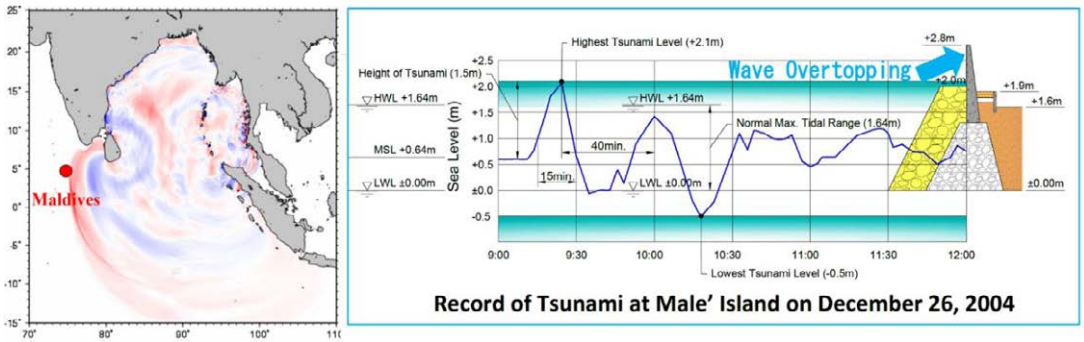
Source: Government of Maldives

Figure 3-1.5 Record of Flood in Male' Island in 1987

(2) The 2004 Indian Ocean Tsunami

On December 26, 2004, at around 8:00 a.m. western time in Indonesia (6:00 a.m. in the Maldives), a magnitude 9.1 earthquake occurred off the coast of Sumatra Island in Indonesia, and the resulting massive tsunami hit the coast of the Indian Ocean. The tsunami struck the Maldives at around 9:15 a.m., about three hours after the earthquake, leaving 108 people dead or missing nationwide. It is recorded that the height of the tsunami that hit Male' Island was about 1.5 meters (Source: Male' Port Tide Level Record), but the seawall designed for the 1987 high waves through Japanese ODA was completed surrounding Male' Island in 2002. Even though there was an unusual wave overtopping as shown in Fig.3.1.7 and the island was flooded, the damage was limited and there were no casualties. The relationship between the tsunami height and the seawall in 2004 is shown in Fig.3.1.6.

The island of Hulhumale was also under reclamation work at the time and did not have a seawall like that of Male' Island. However, the temporary causeway to Hulhumale Island, which was in place at the time, did not protect the international airport from the tsunami, which inundated the airport and caused extensive damage (including the destruction of the floating pier for seaplanes due to the closure of the airport for three days).



Source: JICA Study Team

Figure 3-1.6 Record of Tsunami at Male' Island on Dec. 26, 2004

[6)] The Development Study Report on the Seawall Construction Project for Male' Island conducted in 1992 by JICA
[7)] Although there is no actual record of the event, Dr. Yoshimi Goda of the Port and Airport Research Institute of the Ministry of Transport in Japan, at the request of the Asian Development Bank, determined from weather maps of the Indian Ocean at the time that an abnormal lower pressure system in the waters west of Australia caused waves that propagated to the Maldives as swells.

The East Coast of Male' Island at the time of the tsunami, with overtopping waves and inundation.

Flooding of the West Coast

Ship washed up on the coastal road on the South Coast

Source: TV Maldives

Figure 3-1.7 Record of Tsunami at Male' Island on Dec. 26, 2004

The flooded Hulhule Island (airport island) is on the left, and Hulhumale Island Phase I under development is in the back center.

Floating pier for seaplane collapses.

Flooding in the international airport area

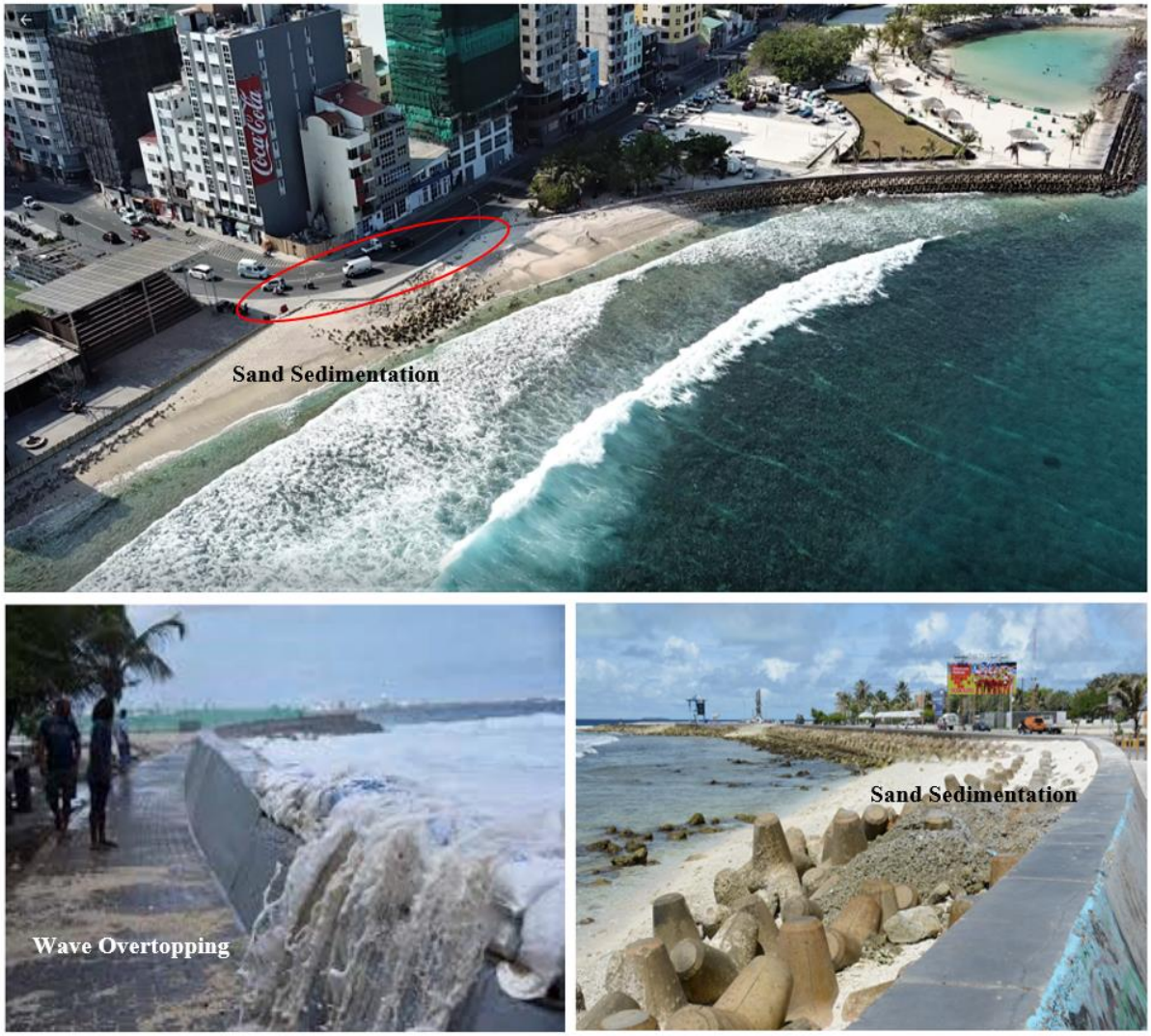
Source: Mr.Todd Rempel (Maldivian Air Taxi Pilot) and TV Maldives

Figure 3-1.8 Record of Tsunami of Airport and Hulhumale Islands on Dec.26, 2004

(3) Wave overtopping in parts of the east coast of Male'

After the 1987 tidal surge, seawalls were constructed around Male' Island by 2002. There has been no serious damage caused by tidal surges or waves in Male' Island since the Indian Ocean Tsunami. However, some parts of the east coast of Male' Island have been observed to have overtopping waves and flying sand. At the southern end of the east coast, coral reefs have developed in a complex manner, and swells from the south break up the reefs. As shown in Fig. 3.1.9, the broken coral sand is concentrated in some areas and contributes to the upwelling of large swells during high tides, causing overtopping and flying sand on the nearby coastal road, and restaurants along the road have made complaints to the government. Due to the widening plan of the coastal road, a part of the seawall location were moved to the sea side in 2018, which ended up reducing the damages by flying sand and overtopping waves. Yet, further measures should be considered to reduce the impact of flying sand and wave overtopping.

In addition, the north side of the East Coast Artificial Beach (Fig. 3.1.10) is subject to constant wave overtopping, making the coastal promenade virtually impassable, and the land behind the seawall is not being used effectively. The area behind the seawall is being developed, and there is an urgent need for measures to prevent wave overtopping.



Source: JICA Study Team, MNPHI (L)

Figure 3-1.9 Sand sedimentation and wave overtopping on east coast of Male' Island

Source: JICA Study Team

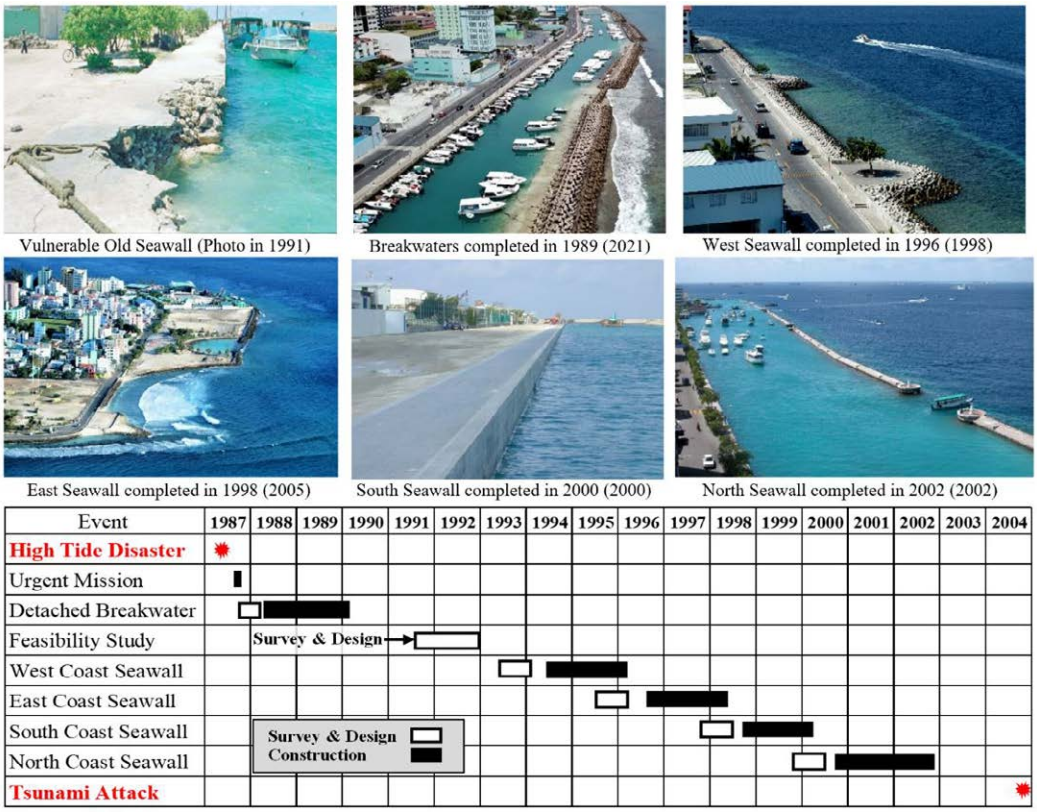
Figure 3-1.10 Wave overtopping on east coast of Male' Island

3-1-3 Current state and issues of disaster prevention infrastructure

(1) Coastal protection facilities on Male' Island through Japanese ODA

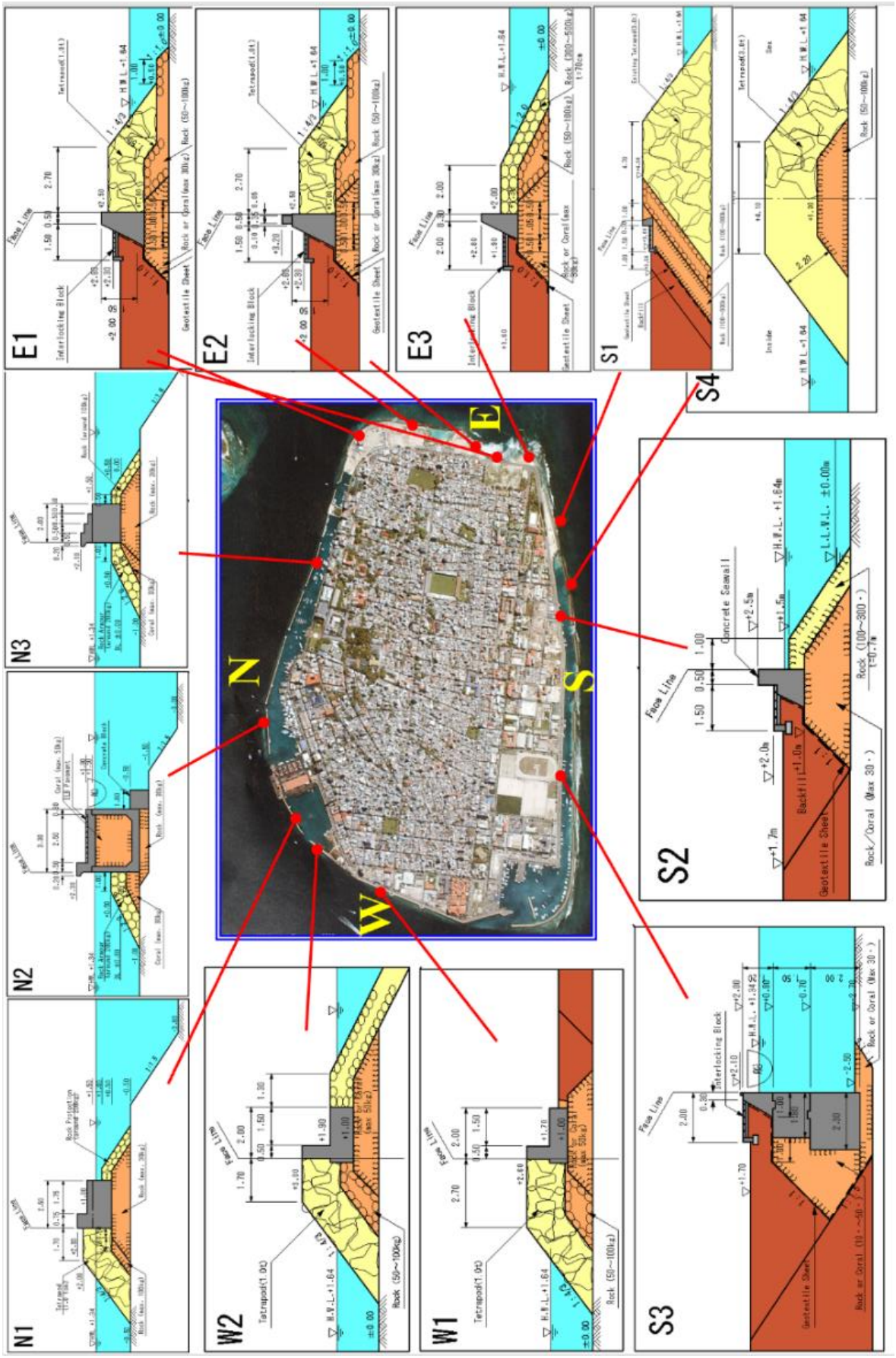
The 1987 tidal wave disaster triggered the construction of coastal protection facilities on Male' Island with Japanese Grant Aid. The chronology of the project is as follows. (See Figure 3-1-11)

- In April 1987, a tidal wave that occurred in the waters of western Australia propagated to the Maldives, attacked the southern coast of Male' Island causing flooding and extensive damage, including the spilling of soil and sand from a large-scale landfill that was being implemented by the government at that time. Japan dispatched an emergency relief team in the same month, and made a decision that it was necessary to urgently improve the vulnerable coastal protection facilities in Male'.
- In July 1987, a survey team was dispatched for 23 days to construct a breakwater on the south coast of Male' Island, and the basic design was carried out immediately.



Source: JICA Study Team

Figure 3-1.11 Male' seawall project and schedule



Source: JICA Survey Team

Figure 3-1.12 Typical section of Male' seawall constructed under Japan's ODA

- From 1988 to 1990, 10 units of detached breakwaters (height +4.0 m, length 125 m/unit) were constructed off the south coast with Grant Aid.
- From 1991 to 1992, a development study on the seawall construction project for Male' Island was conducted for the around Male' Island, and a development plan was drawn up, giving priority to the west coast where hospitals and schools are located, followed by the east coast (reclamation plan), the south coast (expansion of berthing places), and the north coast (reconstruction of aging breakwaters).
- Based on these plans, design and construction of the west seawall (1993-1996), east seawall (1995-1998), south seawall (1997-2000) and north seawall (1999-2002) were carried out with Grant Aid.

The relevant photos of the seawalls and the chronology of the projects are shown in Figure 3.1.11. The typical cross section of the structures of the seawalls in Male' Island constructed by Japanese ODA is shown in Figure 3.1.12. After 2002, some parts of the seawalls have been modified by the new development plan of the Government of Maldives, which will be discussed next.

(2) Current status of coastal disaster prevention facilities on Male' Island

The seawall on Male' Island has been maintained and managed by MNPHI since its construction was completed with Japanese assistance in 2002. Since then, MNPHI has been constructing an artificial beach on the west coast and a new shipping channel on the south coast with its own budget. Part of the east seawall was partially repositioned when the coastal road was expanded. The budget has been prepared according to the major plans in a timely manner. Part of the north seawall collapsed in the 2004 tsunami, but was repaired by a Japanese yen loan project[8]. Some damaged parts of the structure that do not interfere with disaster prevention functions have been left without repairs.

1) West Coast (Figure 3-1.13)

The Government of Maldives constructed an artificial beach on the west coast in 2016 with its own funds, following the model of the artificial beach on the east coast.

Artificial beach on the west coast (red line is the seawall completed in 1996)

Large stones were used instead of tetrapods. This seawall was completed in 1996.

Source: JICA Study Team

Figure 3-1.13 Present situation of seawall on west coast of Male' Island

[8] Yen loan "Maldives Tsunami Reconstruction Project" (Loan Agreement signed in 2006).

At that time, a part of the west seawall (about 380m) constructed by the Japanese ODA was removed, and detached breakwaters and seawalls were constructed at the reef edge to secure the beach area. The seawalls in the artificial beach area are protected by natural stones, and the opening of the beach is narrower than in the east, so the rate of seawater exchange is slightly lower, but the seawalls in the west coast in general have sufficient coastal protection functions against wind waves from the west atoll.

2) South Coast (Figure 3-1.14)

The seawall (quay function) constructed by the ODA on the south coast is usually used by remote island liaison vessels and pleasure boats. At the time of construction, the only entry and exit for ships was the port entrance of the southwest port, which was shared with relatively large ships using the southwest port. Therefore, the Government of Maldives dredged the channel and constructed stone breakwaters on both sides of the channel in 2016. At the same time, in order to expand the south site of the southwest harbor, the two units of west side detached breakwaters were removed. A new stone seawall was built on the south side, which meets the same or better coastal protection function as the existing breakwater.

The red line is the seawall constructed by the ODA project, and the layout has been changed for the new shipping channel and harbor reclamation.

New shipping channel and stone seawall

Detached breakwaters (L) and south seawall with quay function (R)

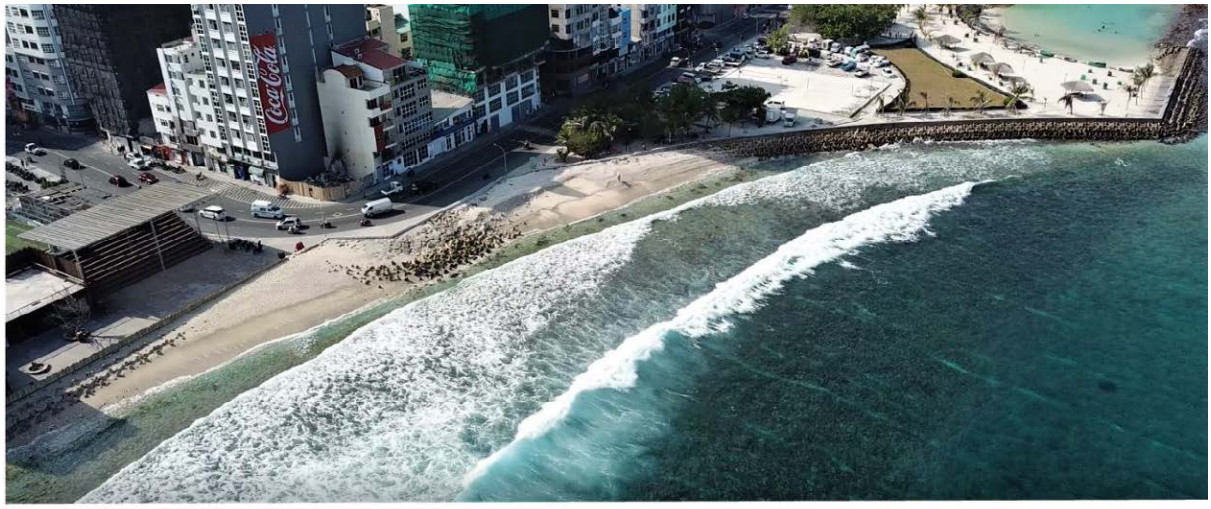
Source: JICA Study Team

Figure 3-1.14 Present Situation of seawall on south coast of Male' Island

3) East Coast (Figure 3-1.15)

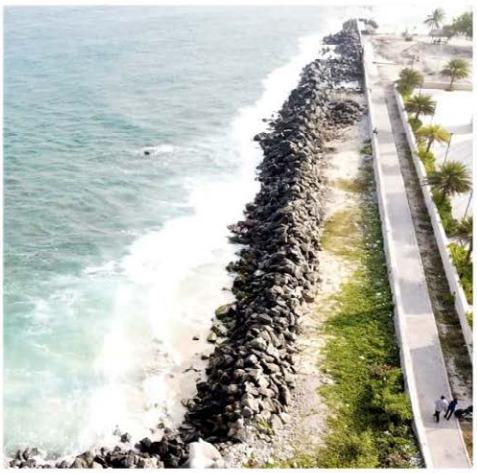
On the east coast, as mentioned earlier, sand deposition and wave overtopping occur in some areas,

so it is considered necessary to employ countermeasures with structures including changes in the seawall location. The southern part of the east coast of Male' Island is the only place around Male' Island where surfing waves are generated. When the plan is further reviewed and considered for implementation, it is necessary to pay close attention so as not to cause excessive opposition from users or, as a result, undermine the function of disaster risk reduction. In addition, an artificial beach has been established on the east coast, which contributes to the health of the citizens. The area around the artificial beach is well maintained and cleaned, and no particular problems have been observed in terms of disaster risk reduction.



Sand tends to accumulate in this area, and there is flying sand on the road.

Artificial beach and neighboring seawall.



The part where some armor stones were added because of overtopping waves.

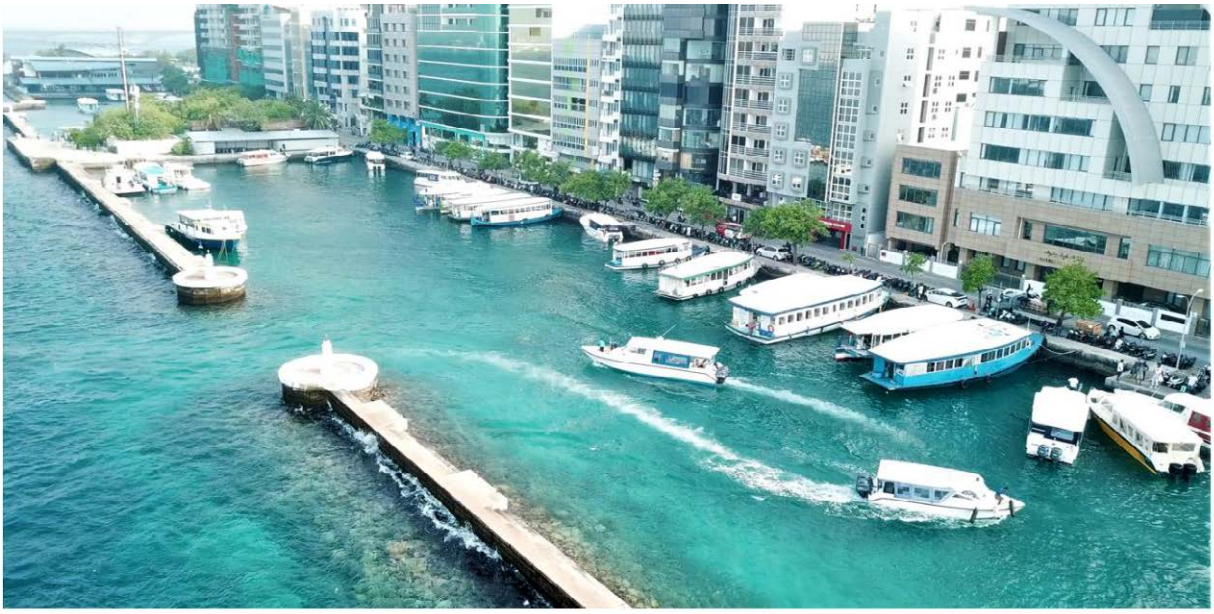
Source: JICA Study Team

Figure 3-1.15 Present situation of seawall on east coast of Male' Island

4) North Coast (Figure 3-1.16)

On the north coast, which is the gateway to Male' Island and used for access to the airport and the entrance/exit for VIP ships, a breakwater with mooring functions for ships and a lighthouse were constructed through Japanese Grant Aid "The Fourth Male' Seawall Construction Project" (1999-2002). Some of the concrete parts of the breakwater have been slightly damaged by ships or mooring ropes, but its function as disaster prevention facility is maintained. A part of the steel sheet pile seawall along the coastal road constructed about 40 years ago collapsed due to excessive water pressure on the sheet piles caused by the abnormally low water level (-0.5 m) during the tsunami in 2004, and the tie rods

broke. As a result, through the "Maldives Tsunami Reconstruction Project" (Loan Agreement signed in July 2006), about 95m of the seawall was extended 5m seaward to reinforce and restore the seawall. In the same restoration area, the upper concrete was displaced due to excessive towing force of moored ships, which needs to be repaired. The rest of the seawalls consisting of sheet pile have not been reinforced, so there is a possibility that they will collapse due to aging. The north coastal road is home to the Office of the President, major government offices, banks, airlines, restaurants, etc. It is a street with a lot of pedestrians and vehicles on the island of Male', and once a disaster occurs, the damage is likely to spread. Therefore, it is suggested that the seawall be reinforced.



The north coast is used as a landing place for boats to the airport and resort islands.

The 95m north seawall that collapsed during the tsunami was restored with a Japan's loan by extending the face line 5m seaward.

The red circle was displaced by the towing force of the ship.

Source: JICA Study Team

Figure 3-1.16 Present situation of seawall on north coast of Male' Island

(3) Current status of coastal protection facilities on Hulhumale Island

Hulhumale Island is an artificial island created by reclaiming a lagoon northeast of the international airport in 1997 to accommodate the growing population of the capital city of Male'. The first phase of reclamation work was carried out by the Government of Maldives, but subsequent investments were made by the government-owned Housing Development Corporation (HDC). The seawall development

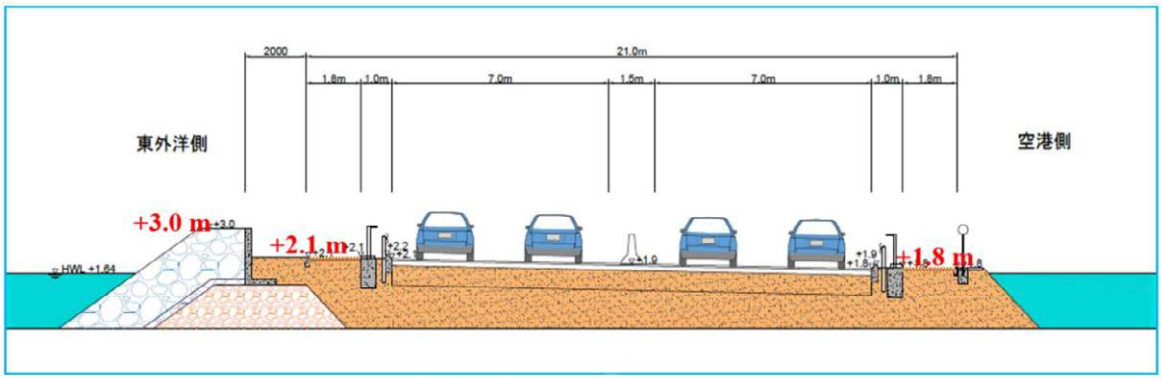
and maintenance of the existing coastline is also being carried out by HDC. In particular, permanent stone seawalls have been constructed on the causeway and the north coast. On the east coast facing the open sea, which is about 4 km long, the sandy beach has been protected with cement bags, but there are many areas that have been scoured and there is no permanent coastal protection.

1) Causeway (Figure 3-1.17)

For the causeway connecting the Airport Island and Hulhumale Island, a stone seawall with a top height of +3.0m is built relatively close to the reef edge to protect the road. It is designed with slope toward the inland sea so that the road will not be flooded even when there is a wave overtopping from the east side facing the open sea. The HDC has plans to install solar panels in the pedestrian walkway (width 3.8 m) (source: HDC planning drawings), but it would be better to raise the top of the seawall or increase the armor stone to minimize overtopping and splashing in order to prevent rusting of the solar panels.

East seawall facing the open sea (the armor stone: +3.0 m)

Pedestrian walkway between seawall and roadway.



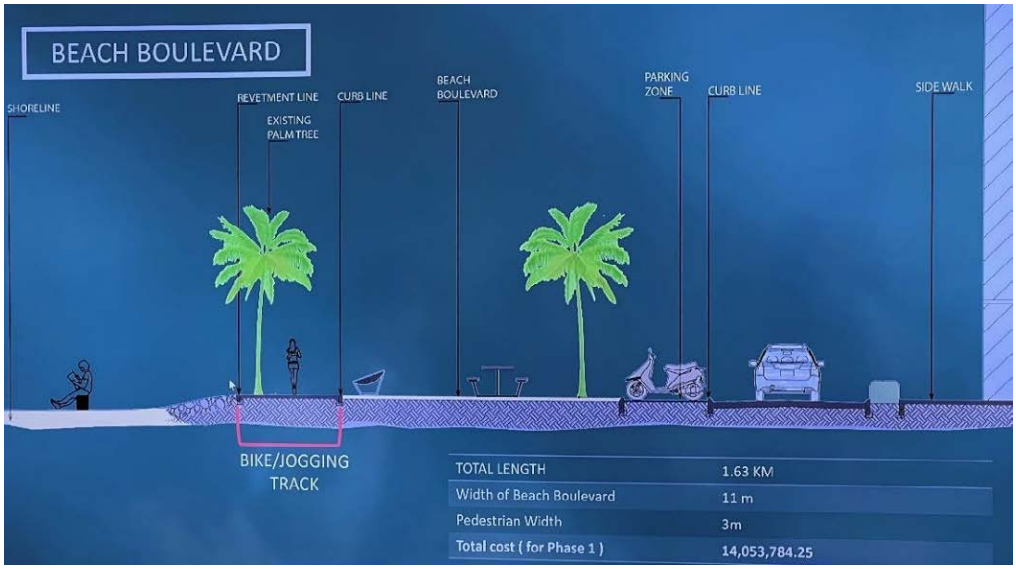
Typical Section of the Causeway

Source: JICA Survey Team

Figure 3-1.17 Present situation of causeway of Hulhumale Island

2) East coast of Phase I area (Figure 3-1.18, 3-1.19)

Almost the same area (188 hectares) as Male' Island was reclaimed as Phase I (1997-2002) (investment: US$32 million (source: UNESCAP: CASE STUDY the Maldives: Leveraging Public Budgets for Coastal Adaptation Projects that include Land Reclamation)). The swell comes from the south of Hulhumale Island and hits the reef edge on the east coast at an almost right angle, breaking the waves. Since the energy of the swell is dissipated in the lagoon, the shoreline is positioned to dissipate the swell energy, leaving a lagoon of about 150 meters[1)].



[1)] HDC Plan Map Source. The east coast road of Hulhumale Island is where hotels, apartments, restaurants, and marine recreational facilities are located. The beach space between the coastal road and the shoreline (about 25m) is owned by HDC as a public beach.

Figure 3-1.18 Planning section of east coast of Hulhumale Island prepared by HDC

The east coast area of Phase I is being developed with hotels, restaurants, and marine entertainment facilities.

The sandy beach is used for recreation by residents. Some of the cement bags installed to prevent erosion have collapsed.

Source: JICA Survey Team

Figure 3-1.19 Present situation of east coast (Phase I) of Hulhumale Island

HDC has a plan to preserve the beach area on the sea side from the coastal road for recreational purposes, as shown in Figure 3.1.19. Therefore, temporary cement bags are used to protect the beach to

control erosion, but they are only placed on the sand. Some of the cement bags are washed away and sunk due to waves, while some cement bags are covered with coral sand. Present beach of +2.2m top elevation seems to be adequate to protect the island and its assets from swell from the open se; however, the behavior of coral sands in the medium to long term may change in the future, and it is important for the Government of Maldives to take measures to protect Hulhumale Island from tidal waves and storm surges as the vulnerability of the island to these disasters is high. In addition, taking into account the future sea level rise due to climate change and the arrival of tsunamis with low but non-zero probability of occurrence, there is a need to develop permanent coastal protection facilities aimed at protecting the lives of the people, their livelihoods and accumulated assets at this point in time while development is in progress.

3) East Coast of Phase II area (Fig. 3-1.20)

Phase II area is larger than Phase I, covering 240 hectares (reclaimed in 2014-16, investment: US$160 million (Source: UNESCAP: CASE STUDY the Maldives: Leveraging Public Budgets for Coastal Adaptation Projects that include Land Reclamation)).

Residential development has not yet progressed in Phase II. The coastal area is wider and more spacious than Phase I area.

The sandy beach was protected by cement bags, but some areas were eroded and others were covered with sand.

Source: JICA Survey Team

Figure 3-1.20 Present situation of east coast (Phase II) of Hulhumale Island

The coastal area of Phase II is almost the same profile as Phase I, with the coastal road and shoreline

preserved. The development plan by HDC includes development of residential areas etc. on the coastal road, but there are still few structures. As in Phase I, the shoreline of Phase II is protected by temporary cement bags, but they are only placed on the sand, and some of the cement bags have been washed away and sunk by the waves. HDC is planning to install more cement bags in order to stop the erosion of the coral sand, but there is a possibility that beach erosion of will progress to the ground level before the reclamation and the erosion will advance to the coastal road. As in the case of the Phase I construction area, the sandy beach with a top height of +2.2m has prevented waves from causing any noticeable damage to the Island at present, but the behavior of coral sand in the medium to long term may change in the future. Considering the importance of the island, as an asset for the nation, and its high vulnerability of to storm surge and tidal surge, there is a need to develop permanent coastal protection facilities as in the Phase I area.

4) North and West Coast (Figure 3-1.21)

Permanent stone seawalls with a top height of +4.0m were constructed between 2016 and 2017 with HDC funding to protect the north and west coasts near the reef edge. The north and west coasts, which are not directly exposed to waves from the open sea, are considered to be adequate for disaster prevention.

On the north coast, stone seawalls sufficient for coastal protection have already been completed.

In some places, sand has started to accumulate.

Source: JICA Survey team

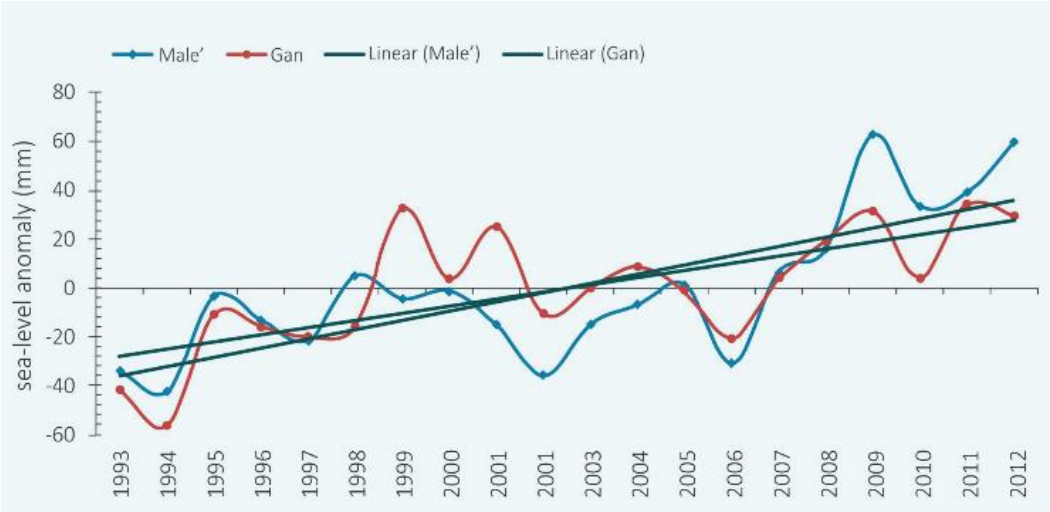
Figure 3-1.21 Present situation of north coast of Hulhumale Islan

(4) Simple survey of the east coast of Hulhumale Island

In order to understand the current topography of the east coast of Hulhumale Island, simple surveys were carried out at seven locations to confirm the ground level. The results are shown in the Appendix, and the coastal road was found to be +2.2~2.3m, and the sandy beach +2.3~2.4m.

3-1-4 Impacts of climate change

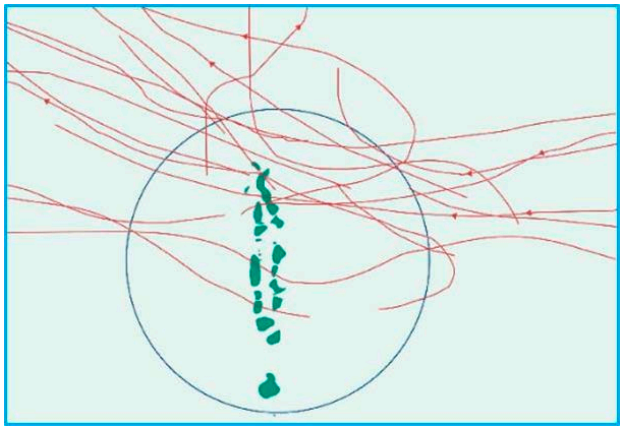
① Sea level rise: According to Second National Communication of Maldives to the United Nations Framework Convention on Climate Change (SNC report) prepared by the Ministry of Environment in October 2016, the average annual sea level rise in Male' Island from 1993 to 2012 was recorded as 3.8 mm, as shown in Figure 3.1.22. The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) announced that the global mean sea level rose by about 0.20 m between 1901 and 2018. The report also announced that the global average sea level rise by 2100 will be 0.28-1.01 m higher than that of 1995-2014. The SNC report predicts a sea level rise of 50 cm (an average of 5 mm per year) by 2100 compared to the year 2000 at Male' Island. In this study, which is intended as an initial and preliminary investigation, we assume that the sea level rise will be 50 cm.



Source: SNC report

Figure 3-1.22 Tidal record of the Maldives from 1993 to 2012

② Cyclones: According to the UNDP 2006 report, there were 11 cyclones that passed through the Maldives between 1877 and 2004, but most of them were in the northern part of the country and few of them passed through Male' Island.



Source: SNC report

Figure 3-1.23 Record of Cyclone passed around Maldives from 1877 to 2004

3-1-5 Cooperation needs for storm surge disaster prevention

- The Government of Maldives has appealed to the world at venues including the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), regarding the problems of coastal erosion and flooding that the Maldives is facing with regard to sea level rise due to climate change. For example, in an interview with the Asahi Shimbun in November 2021, the Speaker of the Parliament of the Maldives, Mr. Nasheed, said that "abandoning the goal of limiting the temperature rise to 1.5 degrees Celsius would be a death sentence for us." As a low-altitude country made up of coral reefs, Maldives is keenly aware of the need to take measures to reduce disaster risks.
- In the case of the Maldives, there is a strong awareness of the need for measures to reduce disaster risk, but the measures to deal with coastal hazards in light of the expected impact of climate change are considered insufficient.
- In the past, there were few experts in the country who understood the unique coastal deformations in the Maldives, but now the human resources are being developed. There is an urgent need to improve the capacity of experts, so that they can lead coastal disaster management initiatives in the country.
- The disaster vulnerability of Hulhumale Island, where 240,000 people are expected to live according to HDC's master plan, is very high, and considering the expected rise in sea level, it is necessary to implement countermeasures as soon as possible.

3-1-6 Cooperation needs for wave observation

(1) Current status of wave observation in the open ocean

The Maldives is subject to waves from the southwest during the monsoon from May to November and from the southeast from December. These waves are from the open ocean and cause damages to the Male' metropolitan area. However, there is no wave observatory in the Maldives and it is not possible to grasp? The wave conditions.

There is a risk that climate change will bring more severe disasters caused by waves in the future. It is necessary to observe waves from the viewpoint of coastal disaster risk mitigation. In particular, the observation of the Vadoo Kandu (Vadoo Strait) between North Male' Atoll and South Male' Atoll is important for the metropolitan area not only for disaster prevention purposes but only for the safe navigation of ships (Source: Comments from MMS at the hearing in Dec. 2021).

(2) Cooperation needs

Wave monitoring provides basic information for countermeasures against storm surge and tidal waves in the metropolitan area. There is a need for cooperation in building a wave monitoring system and establishing its operational capacity. On the other hand, the ongoing JICA technical cooperation "Project for Safe and Resilient Islands against Climate Change and Disaster," implemented in coordination with the Green Climate Fund (GCF) is as follows. The project is planned to be implemented between Oct. 2021and Oct. 2025.

Table 3-1.2 Project for Safe and Resilient Islands against Climate Change and Disaster

Overall goal
Coastal protection measures that take into account the impact of climate change in the Maldives are implemented and resilience and safety of the country against climate change is enhanced.
Project purpose
Capacity of relevant agency staff in implementing coastal protection measures in light of climate change impacts is strengthened.
Outputs
1. Cooperation among relevant organizations in formulating the basic policy of integrated coastal zone management (ICZM) at the national level and specific measures for the populated islands as project sites will be strengthened. 2. A community-driven coastal maintenance and management system will be established on the islands in accordance with the ICZM plan.

3. A long-term monitoring system for waves, beaches, coral reefs and land use will be established on the islands. The operational capacity of relevant agencies will be improved.
Activities
3-1 A wave observation system will be established. Technology transfer regarding use of data for the analysis and operation / monitoring of the system will be established.
Project area
While the target area of the project is the whole of the Maldives, Male' is planned as the pilot site for the outcome 3. The activity related to outcome 3, "establishment of a long-term monitoring system for waves, beaches and coral reefs," will be implemented.
Relevant agencies
This project is a part of "Building Climate Resilient Safer Islands in the Maldives" approved by the GCF For Output 3, MMS and NDMA are the relevant organizations.

As mentioned above, the outputs of this project include the establishment of a wave monitoring system, and it is planned that activities in this area will be carried out using Male' Island as a pilot site. Therefore, this will satisfy the cooperation needs of the MMS.

3-2 Inland Flooding

3-2-1 Natural conditions

(6) Topographic conditions

Both Male Island and Hulhumale Island, which are the targets of the survey, are flat and low-lying lands with an elevation of around 1 to 2 m from the mean sea level. According to the results of interviews with the Maldives Land and Survey Authority (MLSA), there is currently no ground level data, and neither MLSA nor MNPHI plans to prepare a topographic map containing the ground levels.

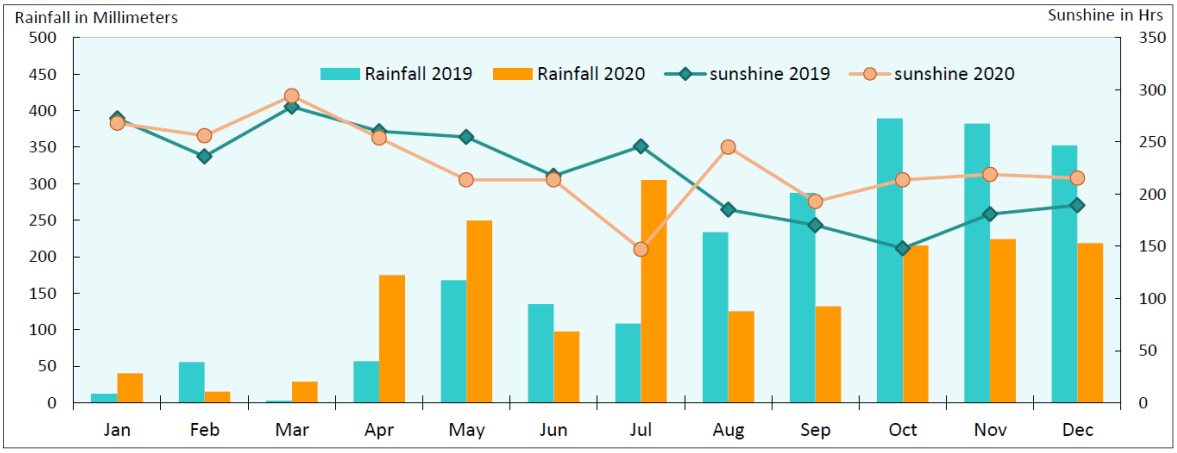
The topography of Male Island does not have depressions that cause floods during rainfall, but the elevation of the west side and the southwest side are lower than the east side, so there is a strong need for inundation measures on the western side of the island.

On the other hand, Hulhumale Island is an artificial island, and the entire island is generally flat, with a ground level of 1.8 m in the Phase I area and 2.0 m in Phase II area.

(7) Precipitation

1) Outline

The Maldives is an island country located near the equator and belongs to the tropical monsoon climate in the Köppen climate classification. According to the Statistical Yearbook 2021, the annual rainfall in Male Island in 2020 was 1,826 mm. As shown in Figure 3.2.1, rainfall tends to be low from January to March. In 2019, monthly rainfall increased from August to December. On the other hand, although the monthly rainfall in May and July is the highest in 2020, the rainfall tends to increase from August to December as well. The hours of sunshine tend to decrease gradually from January to December.

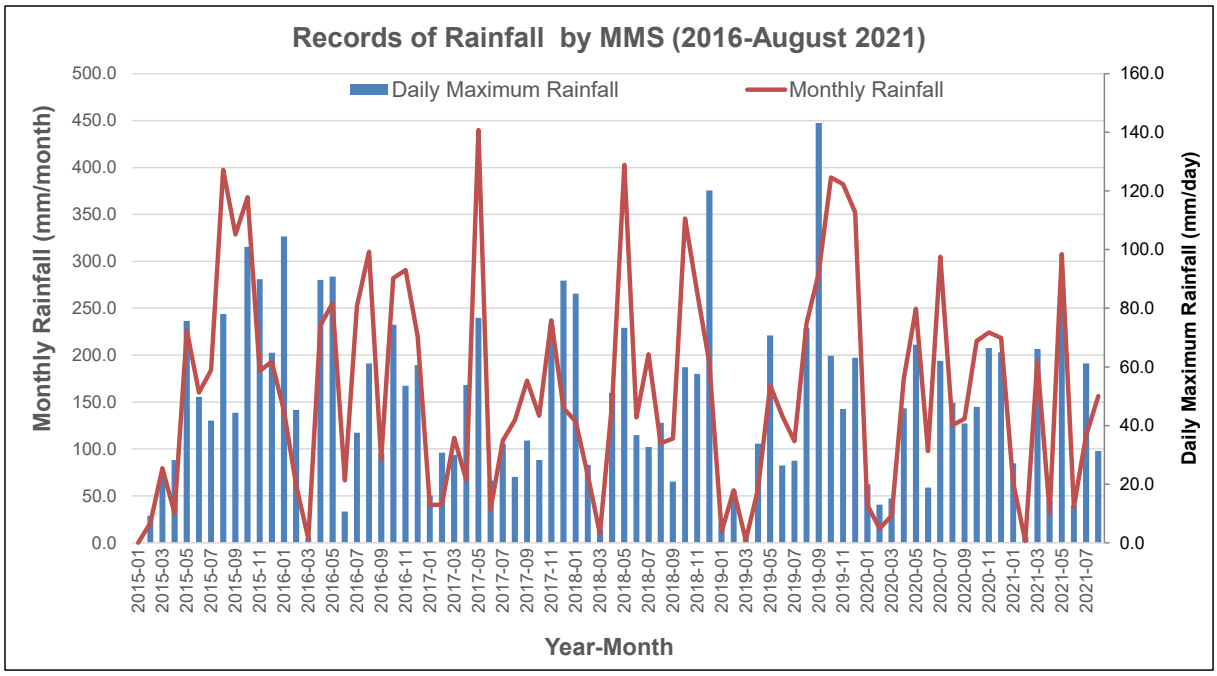


Source: Statistical Yearbook 2021, National Bureau of Statistics

Figure 3-2.1 Monthly precipitation and sunshine hours in Male (2019-2020)

2) Rainfall per day

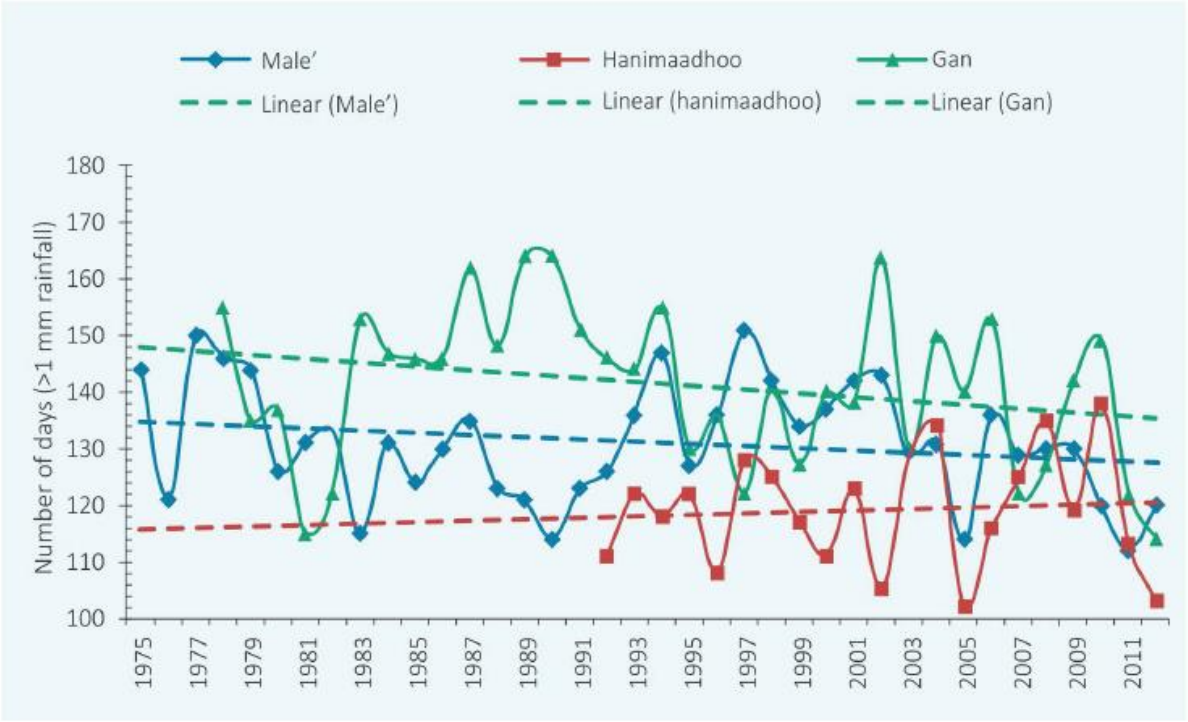
Figure 3.2.2 shows the rainfall data from January 2015 to August 2021 provided by the Maldives Meteorological Service (MMS) under the Ministry of Environment, Climate Change and Technology (MECCT). The daily maximum rainfall for each month is shown in a bar graph, and the monthly rainfall is shown in a line graph. According to this figure, no large annual fluctuations in monthly rainfall are confirmed. On the other hand, the graph of daily maximum rainfall of the month shows the daily rainfall of more than 100 mm has been recorded four times, but daily maximum rainfalls in 2018 (120.2 mm) and 2019 (143.2 mm) increased, compared to 2015 (100.9 mm) and 2016 (104.5 mm). The maximum daily rainfall (24-hour rainfall) in historical record since 1975 in the Maldives is 228 mm/day, observed from November 24 to 25, 2015 in Addu City in the southern of Maldives.



Source: JICA Survey Team based on MMS data

Figure 3-2.2 Monthly Precipitation in Male (2015-2021)

According to the SNC report in 2016, it has been pointed out that the number of rainfall days is decreasing, while the amount of rainfall is increasing in a short period of time as shown in Figure 3.2.3. This trend coincides with the observation data of MMS. During the survey period, a rain gauge installed in the airport island observed rainfall of 133 mm/day on December 11, 2021, and there were three peaks of 31 to 33 mm/hour. In the early morning of December 12, the following day, there was a rainfall of 45 mm/hour. This rainfall was the second heaviest in the last 30 years.



Source: Second National Communication of Maldives to the United Nations Framework Convention on Climate Change, Ministry of Environment and Energy, October 2016

Figure 3-2.3 Annual fluctuations in the number of rainy days

(8) Groundwater level

According to information from HDC, the agency responsible for the development of Hulhumale Island, the groundwater level is around 1.2 m below the ground level. In other words, as mentioned above, the ground level is around 1 to 2 m from the average seawater level, so the groundwater level and the average seawater level are almost the same. The same can be said for Male' Island as written in the report of "The Development Study on the Seawall Construction Project for Male' Island" (JICA, December 1992), it is mentioned that "According to Alasdair J. Edwards (1989), the average groundwater level is 0.4 m above the average sea level, and the layer thickness of the groundwater below the average sea level is 16 m. The fluctuation of the water level is the same as one of the tide level."
Therefore, when constructing underground structures, it is necessary to drain by the pumps in both of Male' and Hulhumale islands.

3-2-2 Overview of the disaster

(1) Flood History

Inland floods have occurred every year in the Maldives, but the exact damaged areas and the situations are unknown because the monitoring regime has not been established.
Since the topography of Male' Island is flat and low in total and there are no depressed areas where rainwater tends to gather, it can be inferred that the floods do not cause as much damage as ones of tidal wave / storm surge, and that it is not a life-threatening inland flood except for basements. In the past inundations, it has been only underfloor inundation, but these inundations are a factor that hinders the socio-economic activities of the dense Male'. Therefore, any improvement for this situation is required.
In addition, regarding road drainage measures on Male' Island, the Male' City Council (MCC) and its commissioned Road Development Corporation (RDC) plan, design, construct, operate and maintain based on the preliminary plan of MNPHI. However, temporary road floods have occurred due to following reasons;

① Roads with concrete blocks do not have a uniform slope, and rainwater on the entire road is not drained quickly.
② There are some narrow roads that take time to drain because the side drains have not been developed.
③ Temporary floods (poor drainage) occur due to insufficient capacities of the drainage pumps. (Sewage pipes are illegally connected to drainage pipes in some households.)
④ Partial cross-sectional blockage / flow obstruction of drainage outlets and stormwater drainage facilities (side drains of roads / rainwater pipes) occurs due to insufficient maintenance of stormwater drainage facilities.

However, the road flooding has been resolved within 3 hours according to MNPHI.

On the other hand, Hulhumale Island is an artificial island created as a relocation site from the overcrowded Male' Island, and is still under development with ongoing construction works. Compared to the fully developed Male' Island, the infiltration area is sufficiently secured in Hulhumale, and the infiltration capacity of sand is still sufficient, so no significant inland water inundation has occurred.

According to the results of hearings with HDC, there is no flood problem in Hulhumale at present, and even if heavy rain occurs, it is drained within 30 minutes. However, the stormwater storage capacity in the basin has been decreasing year by year due to the increase of rainfall intensities in heavy rains and the decrease in green areas by new establishment of parking lots after the development of residential land. And in recent years, it seems that floods occur after 1 to 2 hours of rainfall. This situation is getting worse year by year.

(2) Consideration of flooding conditions

The photographs in Figure 3.2.4 show the situation during and after the heavy rain on December 11, 2021, which was mentioned in 3-2-1 (2). The road flooding has occurred, and it can be observed that

the road was flooded temporarily due to the insufficient capacity of road drainage facilities (side ditches, etc.), cross-sectional blockage, and insufficient capacity of drainage pumps (affected by illegal connection of sewerage). Although the entire island of Male' could not be confirmed, it seems that there are some areas where similar temporary flooding has occurred, and in areas where it takes time for the inundation situation to disappear, improvement of stormwater drainage pipes and pumps would be required.

Road condition after rainfall on December 11, 2021 (Near Henveiru Ground in Majeedhee Magu Rd.)

Road condition after rainfall on December 11, 2021 (Central Part in Majeedhee Magu Rd.)

Road condition after rainfall on December 11, 2021 (Near Henveiru Ground in Majeedhee Magu Rd.)

Road condition after rainfall on December 11, 2021 (Central Part in Majeedhee Magu Rd.)

Source: JICA Survey Team

Figure 3-2.4 Situation in Male' Island during rainfall on December 11, 2021

3-2-3 Current status and challenges of disaster prevention infrastructure

(1) Relevant institutions for stormwater drainage measures

The organizations related to stormwater drainage measures differ between Male' Island and Hulhumale Island. The stormwater drainage facilities on Male' Island have been constructed with planning and designing road drainages by MCC, and pump facilities and stormwater pipes by Male' Water and Sewerage Company (MWSC), respectively, based on the conceptual plan prepared by MNPHI. However, the MCC's plan and the MWSC's drainage facility development are not consistent, and facility development, which should ideally be based on a comprehensive master plan, was done in an uncoordinated manner. It seemed that the coordination among related organizations has been insufficient in the development of drainage facilities for the entire island of Male'. This is supposed to be related to the situation that MNPHI, which is in charge of upper level planning, is not fully aware of the development plans of MCC and MWSC.

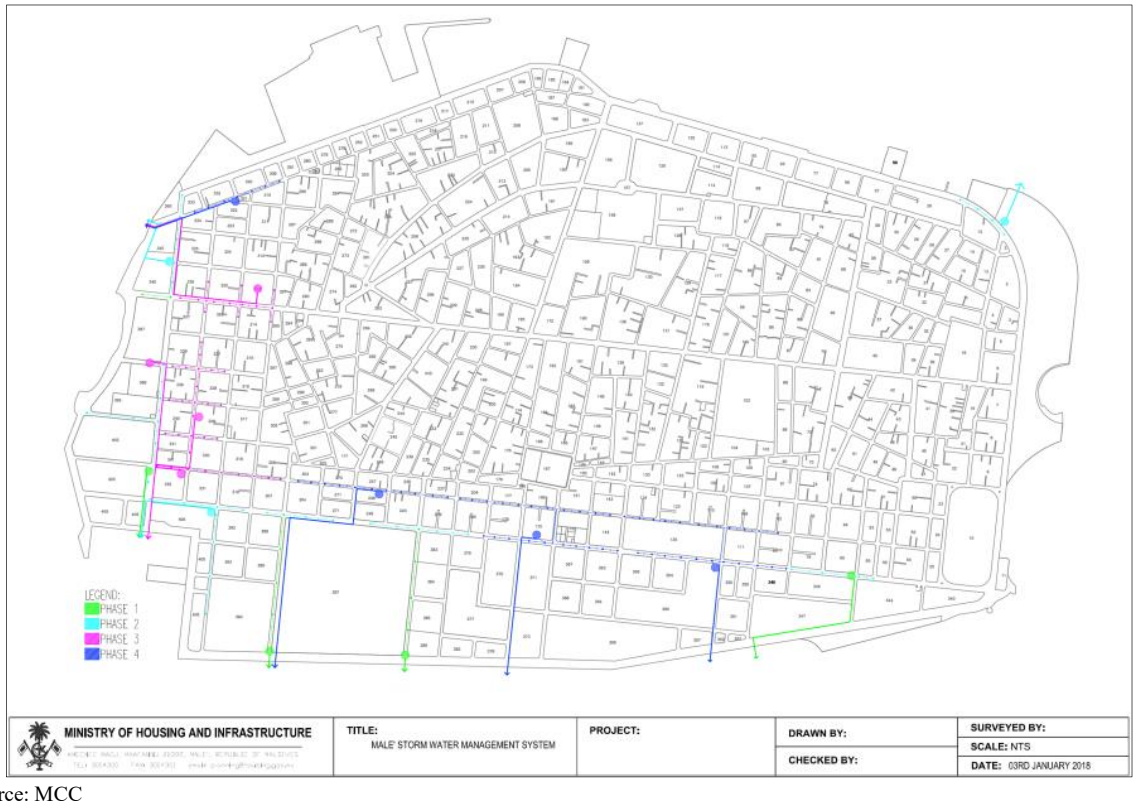
Table 3-2.1 Agencies involved in rainwater drainage works

Activity		Related Agency	
		Male'	Hulhumale
Conceptual plan of drainage facilities		MNPHI	
Road drainage	Design	MCC: Client, Approval RDC: Contractor (Only cleaning of rainwater inlet to stormwater pipes by MWSC)	HDC
	Construction		
	Operation & maintenance		
Stormwater drainage facilities, pumping stations, stormwater storage facilities	Design	MWSC	— (HDC in future development)
	Construction		
	Operation & maintenance		

Source: JICA Survey Team

(2) Condition of the drainage system on Male' Island

On Male' Island, there are 15 drainage pumping stations (PSs) constructed from 2014 to 2018, road gutters with the width of 400 mm and the depth of 600 mm, which was constructed around 20 years ago, and the small gutters constructed more than 40 years ago in both sides of 60 km roads in total. Since the west side and the southwest side of Male' Island are lower than the east side, eight PSs are mainly installed on the west side of the island. In addition, since the ground levels of the south side has increased due to the development of revetments, six PSs have been installed along the main roads on the south side (Ameenee Magu and Boduthakurufaanu Magu). Figure 3.2.5 shows the layout of the PSs and drainage pipes. The funds used for the stormwater drainage project were allocated from the national budget, and these PSs have been operated by MWSC.



Source: MCC

Figure 3-2.5 Pumping station and drainage pipes on Male' Island

The drainage facilities on Male' Island have been installed without the preparation of the stormwater drainage basic plan, and appropriate technical considerations and the validities of facility layouts (drainage capacity evaluation, etc.) cannot be confirmed. Therefore, in this survey, it was verified that inundations due to rainfalls have frequently occurred after the drainage facilities have been constructed.

According to the National Disaster Management Authority (NDMA), in addition to the existing PSs, the Maldives National Defense Force (MNDF), which is also responsible for firefighting and rescue services, voluntarily dispatches their own drainage pump vehicles to drain flooded roads and provide sandbags to prevent inundations inside houses when flooding is confirmed in flood-prone areas during heavy rains.

(3) Status of drainage facilities on Hulhumale Island

For the development of Hulhumale Island, the HDC has prepared a city planning and has also been developing drainage facilities. On Hulhumale Island, drainage channels, drainage pipes, and pump facilities, etc. have not been developed, and rainwater is drained by underground infiltration. HDC takes measures such as creating road slopes to allow rainwater to flow down the plants along the roads, allowing rainwater to flow into the parks, and installing checkerboards (perforated blocks) on the sidewalks to allow rainwater to penetrate into the ground. Hulhumale Island has sufficient green space and vacant land for rainwater infiltration (2 m^2 per capita based on the planned population), and according to HDC, no significant inundation has been confirmed so far. Figure 3.2.6 shows the status of the stormwater infiltration facilities on Hulhumale Island.

As shown in Section 3-2-4, there are concerns that stronger rainfalls would occur in the future due to the effects of climate change, and the infiltration capacity would decline due to the rise of groundwater level. Therefore, HDC recognizes the need for a drainage facility development plan based on runoff analysis.

Underground Penetration System-1 (Phase I Area)

Underground Penetration System-1 (Phase II Area)

Source: JICA Survey Team

Figure 3-2.6 Rainwater infiltration facilities on Hulhumale Island

(4) Maintenance status of stormwater drainage facilities

The stormwater drainage facilities on Male Island are maintained based on an annual plan. There are two types of maintenance, i.e. preventive maintenance and corrective maintenance.

Table 3-2.2 Frequency of maintenance of stormwater drainage facilities (MWSC managed facilities)

Item	Frequency
Cleaning of drainage pipes and wells	2 times/year
Cleaning of pumps with breakdown	1 time/year
Flushing cleaning of drainage pipes	1 time/year
Check of electric lines and control panels	4 times/year

Source: Interview to MWSC

The former includes maintenances and inspections of pumps (impellers, oil leaks, etc.), control panels and pipeline networks, which are carried out at the frequencies mentioned in Table 3.2.2. On the other hand, road drainage facilities are rarely maintained.

In addition, the results of maintenance have been recorded, and necessary parts have been procured on a regular basis. A fixed amount of maintenance budget is allocated to MWSC from the MNPHI every year, but a special budget is set up separately when large-scale repairs are required.

As for emergency response, the check of the pump status is conducted firstly when it rains, and in the event of an emergency such as a disaster, an Emergency Team is formed to take measures such as recovery when the pump is stopped. At the moment, MWSC believes that the engineers for operation and maintenance are well prepared and there is no need for external support. On the other hand, there is also an opinion that they would like to introduce SCADA system (Supervisory Control And Data Acquisition System) for remote monitoring and control to improve efficiency, as the number of vehicles has been increasing and it is difficult to maintain and manage drainage facilities (operation monitoring of multiple PSs).

(5) Status of related projects

In Male' Island and Hulhumale Island, the World Bank (WB) has been implementing the "Maldives Urban Development and Resilience Project (MUDRP)" since 2020. MUDRP consists of the following main project components shown in the table.

Table 3-2.3 Main Project Components being implemented in MURDP by the World Bank

Project contents	Current situation
Sewage treatment facilities on Hulhumale islands	Tender process is on-going. (Technical Evaluation on-going as of January 2022)
Drainage facility, storm water collection and storage facility on Male' and Hulhumale islands	Shortlist is finalized and sent for Bid Committee for getting approval regarding work in Male' Island. (as of January 2022)
Emergency Operation Coordination Center (EOCC)	TOR is under preparation aiming to sign a contract for procurement of equipment in June 2022. Meanwhile, the construction of building has not been commenced and even the location has not been determined.
Strengthening the fire rescue system on Male' Island	Evaluation process is on-going. It is expected to award contract by January 2022
Research on sustainable urban infrastructure and services: research on regional development, affordable housing development, financing options, analysis on feasibility of urban infrastructure and services.	Due to the changes in the Decentralization Act, TOR is being revised and will be shared with WB in December 2021.
Strengthening the Building Code enforcement mechanism: capacity building for staff responsible for building permit and development of online building approval systems	Technical review of Code Compliance Documents is on-going. Consultants are nominated in shortlist, and it is expected to commence work by 15th December 2021.

Source: JICA Survey Team based on MNPHI information and WB interview

WB believes that the risk of damage from more serious inundation and of the damage spreading to higher elevations is increasing on Male' Island, due to the existing stormwater drainage facilities which are aging and lack maintenance. In addition, WB also anticipates that there is a risk of future inundation damage due to the lack of drainage facilities on Hulhumale Island. Therefore, WB believes that it is important to improve drainage facilities on both islands, and is planning the following stormwater drainage projects.

- Preparation of Stormwater Management Master Plan for Male' and Hulhumale
- Upgrade of existing drainage facilities (road gutters) in the priority area of Male' Island (4km in total)

- Construction of stormwater storage tanks at 2 locations on Male' Island and 2 locations on Hulhumale Island (total 2,000 m^3)

The contents of the preceding stormwater drainage project in Male' Island are mentioned below. There are mentions on connecting the rainwater storage tanks to the fire hydrant system, but according to WB, it is a project aimed at eliminating the inundation of the entire Male' Island, with evaluating the drainage capacity of the entire island and developing appropriate drainage facilities.

- Part 1: Surveys and Mapping
  - Collection of all existing information about the most flood prone area of Male'.
  - Update of all public infrastructure developments in the flood prone area, and it should be shown on map.
  - Verification of all available land spaces to place rainwater storage tanks. These tanks are designed to store runoff stormwater to support the newly installed fire hydrant system in Male'.
  - Indication of all blocks such as parks, parking zones, open areas on the map and labelled on the map.
  - The map to be prepared should be indicated topographic figures at a scale of 1:1000.

- Part 2: Stormwater Drainage and Rainwater Storage
  - Estimation of run-off considering maximum recurrence interval, and determination of water volume needed for the hydrants.
  - Identification of possible locations for all rainwater storage tanks.
  - Design of stormwater drainage system to direct flow to water storage / retention ponds and excess flow to sea via gravity and mechanical pumping system.
  - Checking adequacy of the existing stormwater drainage system established in the most flood prone are of Male' and design the necessary upgrading for those systems.
  - In the event that space for the underground or above ground water tank cannot be established, then the central objective would be to move the stormwater in affected neighborhood quickly to the outfalls at the coast using appropriately sized pipes and pumping machines.

Regarding the sewage treatment plant construction project in Hulhumale Island, the contents of the work are as follows.

- The target area is Hulhumale Phase 1 district
- Treatment of sewage sent from existing sewer pipes for a total of 45 km and pumping stations (number of locations unknown)
- The target population is 80,000 residents and 20,000 floating population.
- The scale of the treatment plant is 10,000 m^3/day
- The sewage treatment method is determined based on the contractor's proposal selected from (1) conventional activated sludge method, (2) moving bed biofilm reactor (MBBR), and (3) sequential batch reactor (SBR).
- The sludge treatment method is thickening-dewatering (moisture content 75%) -compost (mixed with biomass such as wood chips)

Table 3.2.4 shows the overall budget scale of the World Bank MUDRP. The total scale of the project is $16.5 million, of which $8.25 million will be loaned and the remaining $8.25 million will be granted.

Table 3-2.4 Budget of MURDP by World Bank

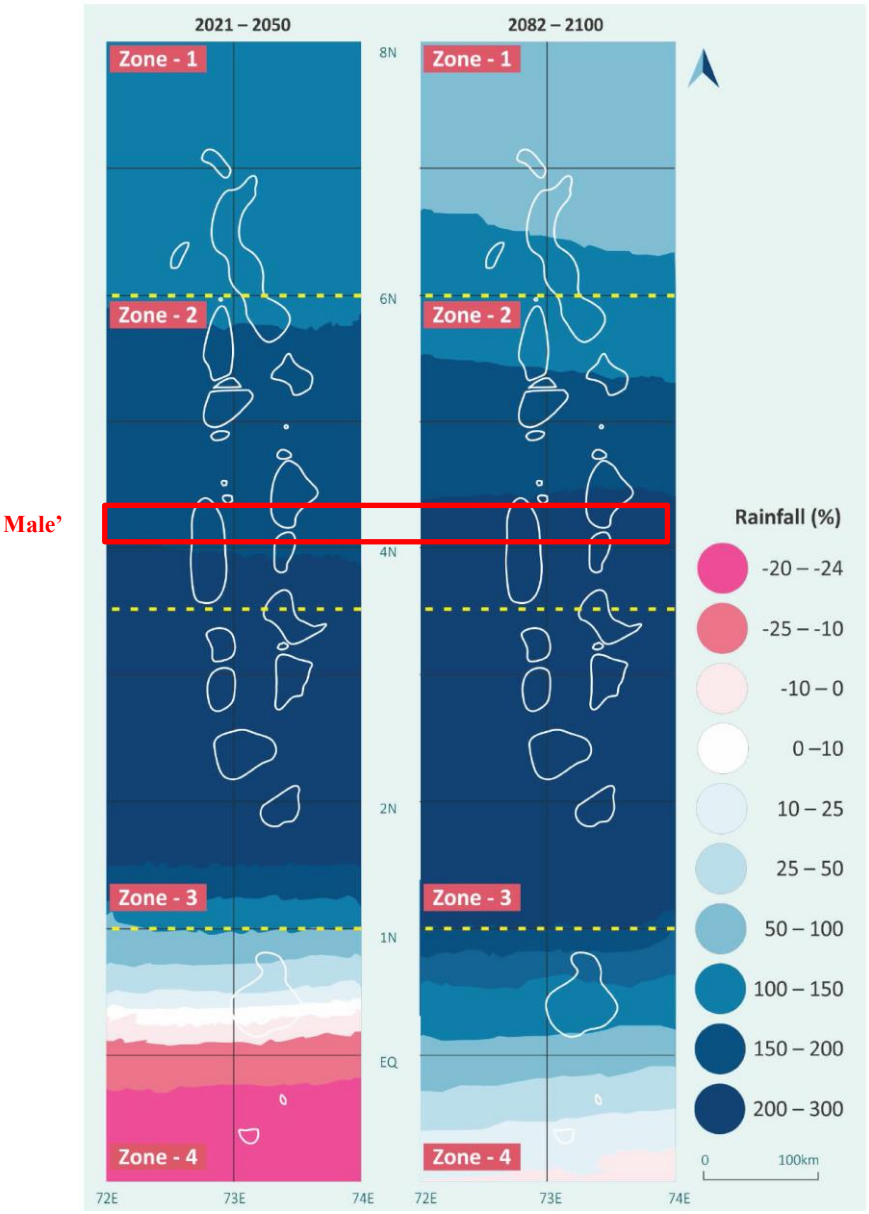
Component No.	Sub-Project/Activity	Amount ($ million)
1	Resilient Infrastructure and Emergency Preparedness	12.5
1.1	Resilient Infrastructure	11.0
i	1. Feasibility studies, design, construction, management, and operations and maintenance of an STP in Hulhumale' Phase 1 2. Feasibility study of an STP in Male' and Hulhumale' Phase 2	6.0
ii	Stormwater drainage masterplan, rainwater harvesting and the	5.0

	upgrading of the primary drainage network in select wards in Male' and Hulhumale	
1.2	Strengthening emergency response systems such as Emergency Operations Coordination Center (EOCC)	1.5
2	Sustainable Urban Planning, Development and Management	2.5
2.1	Analytical studies on sustainable urban infrastructure and services	2.2
2.2	Strengthening enforcement mechanism of building code and regulations	0.3
3	Project implementation, management and reporting	1.5
	Total	16.5

Source: Appraisal document of MUDRP (31st January, 2020, World Bank)

3-2-4 Climate change impacts

According to the "Second National Communication of the Maldives to the United Nations Framework Convention on Climate Change", rainfall in the Male' region is expected to increase to 150-200% between 2021 and 2050, and to 200-300% between 2082-2100, respectively, in comparison with rainfall in 2007.



Source : Second National Communication of Maldives to the United Nations Framework Convention on Climate Change, Ministry of Environment and Energy, October 2016

Table 3-2.5 Projected increase or decrease in rainfall

MMS predicts that the total annual rainfall would be the same as it is now even with climate change, but the rainfall intensity would increase. In addition, when calculated based on the sea level observation records from 2002 to 2020, the sea level rise has been progressing at a speed of 3 to 4 mm per year, and it is predicted to continue progressing at that speed in the future.

3-2-5 Cooperation needs

On Male' Island, as mentioned above, WB has been conducting capacity evaluation and facility development projects for stormwater drainage facilities throughout the island (currently in the tendering stage for procurement of consultant), and there is little room left for cooperation for the development of stormwater drainage facilities . According to the WB, they are not considering projects for operation, maintenance and training related to stormwater drainage. Therefore, there remains possibility of cooperation in the assistance for soft component related to strengthening management capacity and inundation prevention / control.

Regarding Hulhumale Island, although stormwater drainage facilities have not been developed so far, the ground would be covered with pavement and buildings due to the progress of urbanization in the future, and the function of storage and infiltration in the catchments would decline due to the decrease in infiltration area. It leads to the needs of HDC for stormwater runoff analysis and planning of stormwater drainage facilities were identified to cope with the increase in rainfall due to the effects of future climate change. Therefore, there is a possibility of cooperation in conducting a survey on the stormwater drainage facility development plan on Hulhumale Island, taking into account the effects of future climate change and the progress of urban development, but the coordination with WB will be required for it. In an interview during this survey, MLSA shared an opinion that since there is no topographic map in the Maldives, it will be useful for future development if the map would be prepared. As for Male' Island, a 1/1000 topographic map will be prepared in the WB project, so it is recommended to consider the possibility of preparing a topographic map in case the master plan survey on Hulhumale Island would be conducted.

3-3 Impact of Climate-Related Disasters on Critical Infrastructure

3-3-1 Current situation of disaster management

The table below shows the records of damages caused by disasters to water supply, sewage, electricity, telecommunication, schools, hospitals, government buildings, and hazardous materials management. It also shows the state of preparedness for emergency measures in the event of damage on the infrastructure. With the exception of school buildings, no facilities have been damaged by climate-related disasters so far. For these infrastructure, the business continuity plans (BCPs) have been established or being prepared to deal with damage in the event of a disaster.

Of these, water supply and electricity supply network are connected between Male' and Hulhumale islands. In the event of a disaster, the two islands can complement each other. Even if the function of one island is damaged, a redundant system has been established to receive supplies from the other island. One of the factors behind the implementation of these measures is the recognition of the need for crisis management as an infrastructure company, presumably based on past experiences with storm surges, tsunamis, and inland flooding. Schools have suffered damage due to climate-related disasters. The examples are explained in the table below. Measures are needed to drain rainwater that forms puddles in school grounds.

Table 3-3.1 Records of damages to infrastructures and ther reparedness

Water supply (MWSC, Male' Water and Sewerage Company)	
Records of damages	So far, no water supply facilities in the Male' metropolitan area have been affected by climate-related disasters.
BCP	Currently being prepared (as per MNPHI instructions)
Alternative systems for disaster occurrence	The water supply facilities of Male' and Hulhumale islands are networked. Water pipes are redundantly installed on the bridge between the two islands. Cross-subsidization is possible. There are desalination facilities on both islands.
Sewerage facilities (MWSC)	
Records of damages	There has been no climate-related damage to sewerage facilities in the Male' metropolitan area. The only existing sewerage facilities are drainage pipes. There are no treatment plants in the metropolitan area.
BCP	Currently being prepared (as per MNPHI instructions)
Electric power supply (STELCO, State Electric Company Limited)	
Records of damages	There has been no climate-related damage.
BCP	Currently being prepared (as per MNPHI instructions)
Alternative systems for disaster occurrence	The power transmission facilities on Male' and Hulhumale islands are networked. A transmission line is installed on the bridge between the two islands. Mutual complementarity is possible.
Telecommunication (PSM, Public Service Media)	
Records of damages	There has been no climate-related damage.
BCP	BCPs have been prepared for Dhiraagu[1)] and Ooredoo[2)]. 1) Major internet providers in the Maldives 2) Major digital service (sim card, payment, etc.) providers in the Maldives
Schools under Ministry of Education[1)]	
Records of damages	・Walls, floors, ceilings, furniture, etc. of school buildings have been damaged by heavy rains, floods, strong winds, etc. ・After heavy rains, water is stagnant in the schoolyard, making it difficult to use it. ・In December 2021, Hiriyaa School and Thaajuddheen School were damaged by floods. ・In 2021, Iskandhar School on Male' was damaged by falling trees by strong winds. ・There has been no damage caused by storm surges or waves since the 2004 tsunami.
SEOP	The preparation of a School Emergency Operation Plan (SEOP) has been made mandatory by the Ministry of Education on2011. The plan is prepared for each school. However, there is a lack of knowledge in the field DRR among teachers, which is an issue to be addressed.

	Strengthening its operational system has been a challenge.
Other measures	・The schools regularly conduct DRR drills with the cooperation of the National Defense Force (MNDF). ・In the event of a disaster, the schools receive necessary support through coordination with the NDMA. ・Rainwater tends to be stagnant on school grounds, but there is no system to drain it. ・There are structural regulations in the building code, but they do not take into account disaster preparedness or the worst-case scenario of future climate change. ・Some of the school buildings in the metropolitan area are in need of repair due to their poor structure, including a 10-year-old school in Male' that needs urgent repairs. ・Fire prevention measures are not fully functioning in the schools. Fire extinguishers are installed, but the buildings are not equipped with sprinklers. Only about two schools have fire hoses. ・Fire extinguishing systems in schools are not in place in older schools, but are in place in newer schools.
Hospitals under Ministry of Health	
Records of damages	A hospital in the southwestern district of Male' Island experiences inconvenient traffic on the surrounding roads during inland flooding.
BCP	Emergency response operation plan has been prepared under the direction of Ministry of Health.
Government buildings	
Records of damages	There has been no Records of damage to government buildings in the metropolitan area.
BCP	Some government agencies have already prepared BCPs. The NDMA does not have a BCP. It is not mandatory for government agencies to prepare BCPs for their buildings.
Other measures	Government buildings are not equipped with sprinklers.
Hazardous chemicals and dangerous materials that can lead to fire	
Future plan	There are plans to centralize all facilities that store hazardous chemicals and materials that can lead to fires in Gulhifalhu and Thilafushi,.

Figure 3-3.1 Desalination plant at MWSC

Figure 3-3.2 Thermal power plant at STELCO

Figure 3-3.3 A school, Southwest of Male'

Figure 3-3.4 Dharmabandha Hospital, Southwest of Male'

3-3-2 Cooperation Needs

In the areas of power and water, its supply systems have been connected between Male' and Hulhumale islands to complement each other in case of a disaster. Agencies of water, sewerage, electricity, and telecommunications are working on creation of BCPs. As such, critical infrastructure can be considered prepared or being prepared for disasters and cooperation need in this field is low. In schools, SEOPs have been prepared. On the other hand, the implementation of the SEOP is still a challenge due to the lack of knowledge/experience of teachers. There is damage to school facilities every year, while countermeasures for wind and fire extinguishing equipment are provided by the national budget. There is a need to improve drainage in school grounds.

3-4 Human Resource Shortage

3-4-1 Availability of staff with expertise in agencies

The status of civil engineers in the agencies described in Chapter 2 is summarized in the table below. The agencies lack engineers in the fields such as storm surge and inland flooding control. Most of the engineers in these agencies have obtained their degrees abroad, and the number of these engineers is limited. The universities in the Maldives do not provide sufficient practical knowledge in these fields, which leads to the difficulty in these agencies' recruitment of technical staff.

Figure 3-4.1 Staff with expertise in agencies

MNPHI
・There is a shortage of engineers with expertise in urban drainage, storm surge and coastal erosion. ・Civil engineers have degrees from universities in Europe, the United States and Australia but may not have sufficient field experience and practical knowledge.
HDC
・There are staff with expertise in architecture, urban planning and general civil engineering, but no staff with expertise in urban drainage or coastal engineering. ・HDC has difficulty in conducting detailed design for infrastructures such as drains or seawalls . ・Surveying is necessary, but there is a shortage of engineers.
MMS
・There is no meteorological institutes in the Maldives and students are studying in India, China, Japan and South Korea. ・There is no research staff in the research section on climate change.
NDMA
・Training is important for staff involved in DRR, and educational programs are necessary. Training has been provided by Japan (JICA), Singapore, the United States (Hawaii), Bangladesh, the UN, etc.. ・The training in Japan includes technical training by JICA, KCCP1 in Kobe (2017), and one-year study abroad program at Tsukuba University (2020~2021). ・The number of staff is planned to be increased by 3 to 4 and would like them to experience training in Japan. ・Support from Japan and other countries for human resource development has increased staff awareness, which in turn has become a driving force for strengthening organizational capacity, creating a positive cycle. ・There is no program in national universities that focus on DRR at this moment; therefore, it is difficult to obtain knowledge on DRR in the Maldives. A staff member studied DRR at AIT (Asian Institute of Technology, located in Bangkok).

3-4-2 Current status of education and research activities of higher education

The Bachelor of Civil Engineering in the Faculty of Engineering, Science and Technology of the Maldives National University (MNU) has 36 subjects in its curriculum (Appendix 4). Among these, the subjects of hydraulics and hydrology offer knowledge related to flood control, but there are no courses or laboratories related to urban drainage which offers insight into practical aspects. Therefore, although students can learn basic knowledge, they cannot adequately deal with specific issues that are actually required onsite. Currently, students are unable to acquire practical knowledge related to drainage facilities needed in the metropolitan area including planning and design of those facilities.

With regard to coastal engineering, while the subject is offered, there is no research activities on the actual issues occurring in the metropolitan area. The issues surrounding coastal engineering / coastal disaster management in the metropolitan area could be research topics, the results of which would be fed back to the real-life maintenance management, new planning, or design of coastal facilities. There seems to be a gap between acquiring the knowledge and using the knowledge to practical use.

In classes on hydraulics, hydrology, and coastal engineering, it is necessary to learn not only about the movement of water, waves and sand, but also to link this to disaster countermeasures. With regard to storm surge and inland water flooding, it would be necessary to supplement and improve the course, so that students can respond to problems that actually occur in the metropolitan area.

3-4-3 Cooperation needs

As mentioned so far, challenges exist in the development of human resources with expertise of coastal engineering and urban drainage. There is a need for cooperation in the fields of education/training and research. Past cooperation by JICA including training programs in Japan on the field of DRR, has been proven to be effective, and its continuation is recommended.

3-5 DRR Education in Schools

3-5-1 Current status of DRR education

The devastating Indian Ocean Tsunami in 2004 revealed the vulnerability of the Maldives to disasters, which also had an impact on the education sector. In 2009, the School Emergency Operation Plan (SEOP) Guideline was developed as a response to the disaster. In 2011, all the schools are required to prepare SEOPs. In 2018, DRR education was introduced in school education [1)]. Although these systems are in place, there are many areas for improvement in their implementation.

DRR education has not yet been developed into a curriculum, and the content at this stage is insufficient, limited to teaching the types of disasters, etc. The teachers do not have thorough knowledge of DRR. The Records of disasters in the area or evacuation methods based on topography are not taught as is the case in Japan. There are cooperation needs for creating a curriculum on DRR and guideline for teachers.

1) Ministry of Education: Maldives Education Sector Analysis Feb. 2019, P.31, 127

3-5-2 Awareness of citizens and politicians on DRR

Regarding the occurrence of disasters in the Male' metropolitan area, the damage is moderate compared to the high vulnerability of the area. Although floods occur every year, they cease within a few hours. There has been no major coastal disaster damage since 2004. For this reason, the importance of disaster prevention does not seem to be well recognized among citizens. Politicians also may not recognize the needs for DRR measures nor the severity of future disasters with the impact of climate change. It is important to increase the awareness among general public of disaster management and DRR measures. It is hoped that once students gain knowledge of disaster prevention in schools, this knowledge will spread to their families and neighborhoods, and in the long run, greater awareness of disaster risk can shift the society and politics towards mainstreaming DRR.

3-5-3 Cooperation needs

In order for students to have a proper understanding of the current situation of disaster occurrence in the metropolitan area, the mechanism of occurrence, disaster prevention measures, and the impact of climate change, DRR education should be promoted. At present, there are no curricula for this purpose and no training guidelines for teachers. There is a need for cooperation to address this situation.

Chapter4 Outlook of JICA's Proposed Cooperation

This chapter discusses countermeasures against climate-related disasters, responding to the issues discussed in Chapter 3, and the outlook of proposed cooperation.

Due to the effects of climate change, the global average sea level is expected to rise by 71 cm by 2081~2100 in the worst-case scenario. The Government of Maldives expect the sea level to rise by 50 cm by 2100, and the increase of rainfall intensities is also predicted. The sea level rise and the associated storm surge countermeasures are considered to be extremely urgent challenges for the Maldives. Therefore, a need exists to construct and reinforce coastal revetments on the two islands in the Male' metropolitan region. From the perspective of exposure to disaster risks, the new seawall constructions on the east coast of Hulhumale' Island, which faces the open sea and currently has no permanent seawall, and reinforcement of the existing east coast seawall on Male' Island, where wave overtopping and flying sands is observed, are identified. In addition, the north coast of Male' Island would also be taken into account for reinforcement as there are some damages.

In addition, insufficient capacity of the storm water drainage system on Male' Island has resulted in inland floodings during the rainy season, causing disruption to the lives of citizens and economic activities. On Hulhumale' Island, as development progresses in the future, the rate of storm water runoff will increase, and the impact of inland flooding may become severe. The risk will increase as climate change intensifies the rainfall pattern. Hence the elaboration of master plans for rainwater drainage in these two islands is also a challenge to be addressed.

In addition, there has been a shortage of technical staff in government agencies and public corporations such as MNPHI and HDC, which are working to respond to these issues. In order to fill this gap and to improve the professional capacity in the field of coastal engineering and urban drainage, technical cooperation with government agencies and practical education and research programs by MNU could be considered.

While the 2004 Indian Ocean Tsunami revealed the vulnerability of the Maldives to disasters, it is true that Male' Island could mitigate the impact by the tsunami, due to the fact that the seawalls protected tidal waves and storm surges to some extent. On the other hand, even with these seawalls, the disaster risk cannot be completely eliminated. The Indian Ocean Tsunami also brought about changes in the education sector, with SEOPs being developed in schools and disaster education being introduced in 2018. However, the development of the curriculum is still in its initial stage, and there is a need for cooperation to the development of the curriculum, teaching materials/text books and teachers guideline. It is expected that the knowledge gained by students through disaster education in school will be extended to their homes and communities, leading to an increase in disaster awareness in society as a whole, which will also contribute to promote construction of structural measures including its maintenance in a long run.

The information presented in this chapter, such as natural conditions in the Male metropolitan area, is of preliminary stage, gathered through interviews or document analysis. In discussing necessary measures in the following study stages, its design and construction method shall be further scrutinised. In particular, detailed investigation on the meteorological and geological conditions will be essential. Exposure to anticipated hazards in the region (especially the level of protection to be set for structural measures) and urgency of implementing countermeasures should be discussed in determining the next step of action.

4-1 Storm Surge

This section describes the projected sea level rise in the Maldives due to climate change, how this will affect coastal disaster risk reduction in the Male' metropolitan area, and what measures are urgently needed. In Chapter 3, the current status and problems of coastal DRR facilities in Male' Island (4 coasts) and Hulhumale' Island (4 coasts) are described. Based on this, four coastal protection facilities are

identified: two sections on the east coast of Hulhumale' Island, two sections on the east coast of Male' Island, and reinforcement of the seawall on the north coast of Male' Island. In particular, this survey identified that the Hulhumale' Island should avoid the experience of the 1987 disaster of Male' Island, which was caused by the development to the edge of the coastal area. The design of some of the seawalls on Male' Island, which were constructed in the past through Japan's Grant Aid, should be reevaluated in view of the severe natural conditions and the increased risk of climate change. In addition, some of the seawalls of the main coastal road on the north coast of Male' Island were damaged by the 2004 Indian Ocean tsunami, which exceeded the design external force. Other parts of the seawall along the coastal road are also deteriorating, and its reinforcement may need to be addressed.

4-1-1 Elevation of seawall plan considering sea level rise

The sea level rise due to climate change was not taken into account in the design conditions for the Male' seawall project implemented by Japan's Grant Aid from the 1980s to the 2000s[1)]. This study, which is an initial study, will take into account today's climate change projections. Specifically, as described in section 3-1-4, the Government of Maldives estimates that the projected sea level rise in the Maldives will be 50 cm by 2100. In this study, the planned maximum tide levels for the east coast of Male' and Hulhumale' islands are considered as follows. It should be noted that the following is for the purpose of initial study, and the specifications of the structures should be determined after more detailed study in consideration of natural conditions.

1) Lowest sea level is set at +0.0 m, the mean sea level is +0.64 m and the highest sea level is +1.34 m in Male' Island.
2) Both Male' and Hulhumale' islands have lagoons in front of the target coast. Therefore, a wave setup (water level rise) of about 0.30 m occurs. Therefore, considering this setup, the highest sea level is +1.64 m (+1.34 m+ 0.30 m= +1.64 m).
3) If the sea level rises by 50 cm in the future, the highest sea level will be +2.14 m (+1.64 m + 0.5 m = +2.14 m) considering the setup.
4) The planned top elevation of the seawall is usually equal to the highest sea level plus the planned wave height (H=1.3 m) (JICA Development Study on Male' Seawall Construction 1992). In other words, +2.14 + 1.30 = +3.44 + α = +3.50 m.

1) After the "Construction of detached breakwaters on the south coast of Male' Island" (Grant Aid) (1987-89), the "Development Study on the Seawall Construction Project for Male' Island (1991-92) was conducted. And the "Male' Island Seawall Construction Plan" (Grant Aid) (1994-96) for the west coast, the "Second Male' Island Seawall Construction Plan" (Grant Aid) (1996-98) for the east coast, the "Third Male' Island Seawall Construction Plan"(Grant Aid) (1998-2000) for south coast and the "Fourth Male' Island Seawall Construction Plan"(Grant Aid) (2000-02) for north coast were implemented.

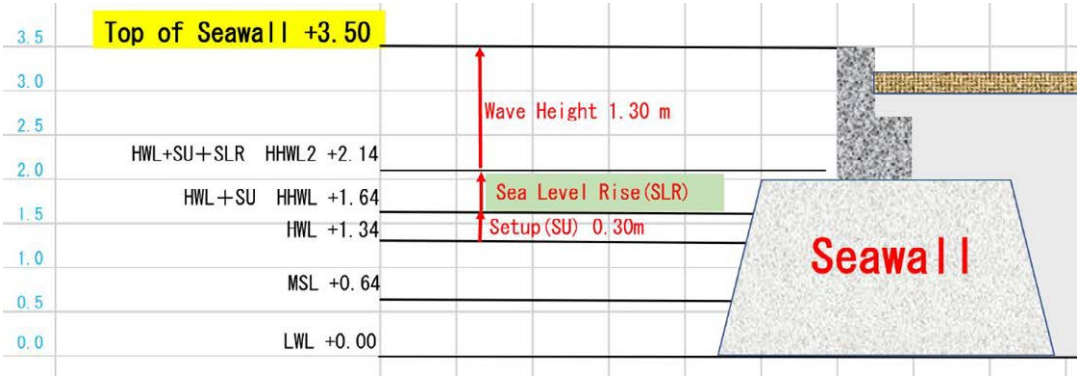


Figure 4-1-1 Relationship between sea level rise and seawall height (initial study)

4-1-2 Countermeasures against storm surge and tidal waves

The current status of coastal protection facilities was assessed through the field survey in Male' and Hulhumale. The exposure to disaster risk of the Male' metropolitan area, for its geographical and social

elements, is high as is the need for disaster risk reduction. Construction or improvement of the following four coastal protection facilities are considered necessary to reduce disaster risk in the Male' metropolitan area.

- New construction of seawall (2,300 m) on the east coast of Hulhumale' Island (Phase I area)
- New construction of seawall (1,600 m) on the east coast of Hulhumale' Island (Phase II area)
- Reinforcement of the existing seawall (140 m) and (100 m) on the east coast of Male' Island
- Improvement and reconstruction of the seawall on the north coast of Male' Island (95 + 609 m)

In this section, the project outline is discussed based on the conditions shown in 4-1-1.

Figure 4-1.2 Location map of the proposed seawalls

(1) New construction of seawall on the east coast of Hulhumale' Island (Phase I)

As shown in the HDC master plan in Figure 4.1.3, the east coast of Hulhumale' Island is planned to be protected as Open/Green Space and used for beach recreation. In the east coast of Phase I area, there is a sandy beach of about 25 m from the coastal road to the shoreline. The current road elevation is +2.2 m and the sandy beach is about +2.4 m. Considering the natural conditions of Hulhumale' Island and the sea level rise, the island does not have sufficient disaster prevention capacity, and a need exists to construct a new permanent seawall. The following points should be noted regarding this proposal.

- It is important to manage the coastal area in such a way that it does not repeat the dense development of the Male' Island coastal area.
- Close consultation with HDC and MNPHI is necessary from the planning stage for the implementation of the project.
- It is necessary to conduct an environmental assessment at the stage when the outline plan is decided.
- It is necessary to implement a system that does not interfere with residents' use of the beach and traffic during the construction phase with the cooperation of relevant parties.
- The HDC is expected to be in charge of maintenance and management after the construction is completed, but its responsibility and management needs to be clarified.

The following is an example of the construction procedure. As this survey is an initial study for the

seawall construction and improvement, the specifications of the structure should be scrutinised in consideration of more detailed natural conditions. Construction procedures (initial idea) are indicated in Appendix 6 for reference. In addition, the shoreline of the sandy beach in the cross section shown below is only an indication of the current situation.

Example of construction procedure

1) Establish a seawall face line 15 m seaward from the edge of the coastal road. Excavate the current sandy beach to the seabed of the original lagoon (+0.0 m) at the seawall location. A stone foundation will be built there.

2) A concrete seawall with a top elevation of +3.5 m will be installed on the stone foundation.

3) Armor stones of 1 to 2 tons are placed in front of the concrete seawall. A permanent seawall consisting of stone foundation, concrete seawall and armor stones is completed.

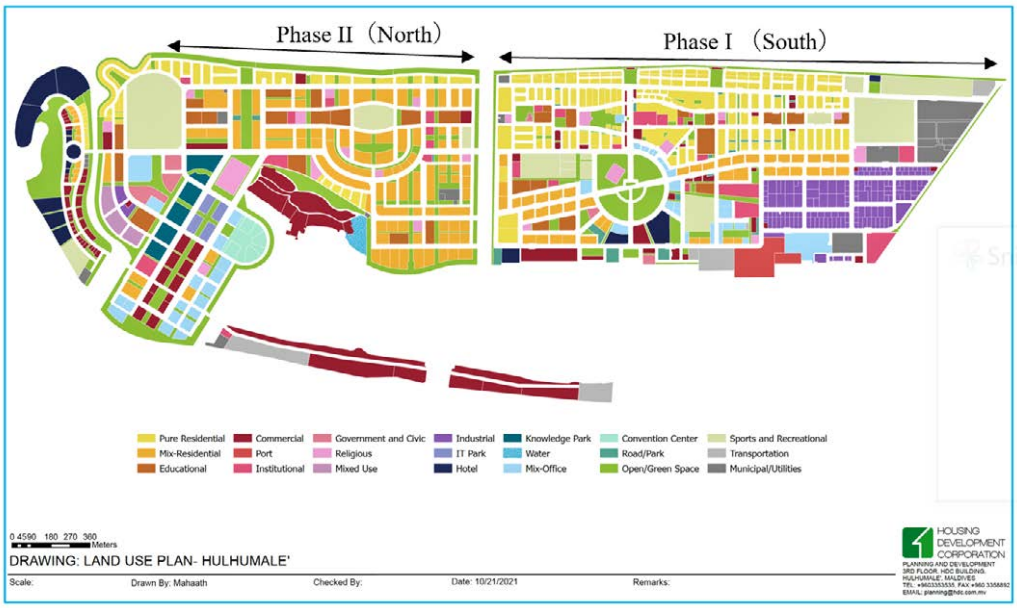
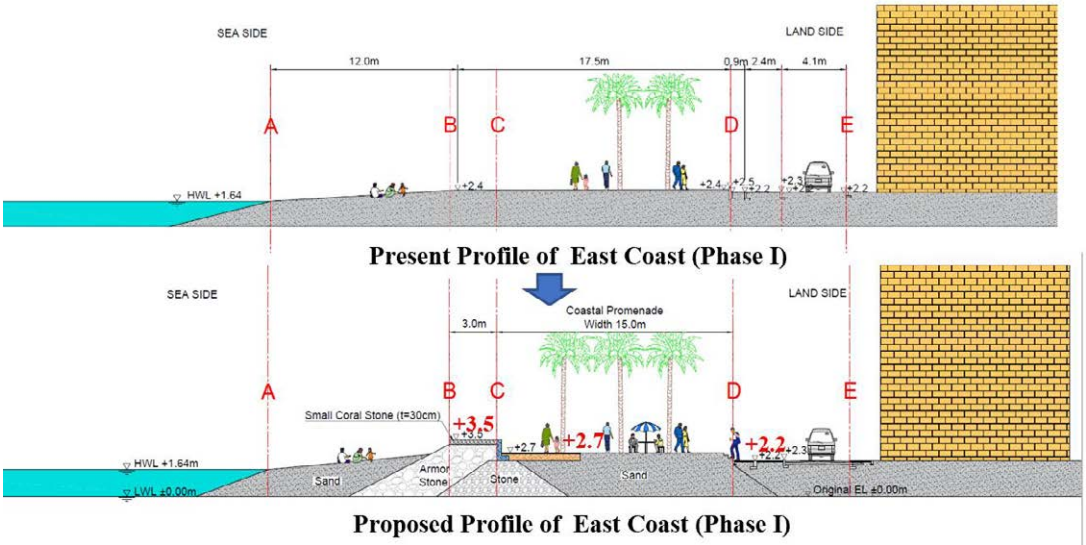


Figure 4-1.3 Land use plan of Hulhumale' (as of October 2021)



Note 1: This proposed profile is for the initial study. The location of the sandy beach on the seaward side of the seawall is depicted based on the current sandy beach location, and the specifications of the structure should be determined after a detailed assessment of natural conditions.

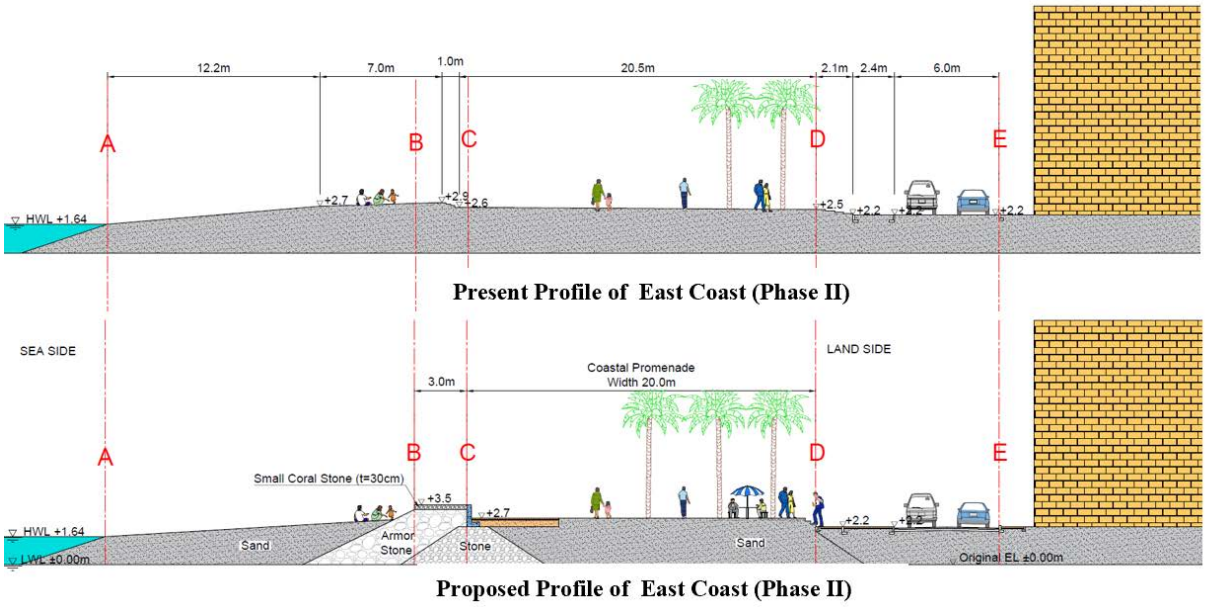
Note 2: There was a request from HDC to make the height of the sandy beach on the landward side of the seawall the same as the height of the main body of the seawall +3.5m. This will require further study.

Figure 4-1.4 Proposed seawall plan of east coast of Hulhumale' Island (Phase I)

(2) Newly constructed seawall on the east coast of Hulhumale' Island (Phase II)

The east coast of Phase II has almost the same shape as Phase I, but the distance from the coastal road to the shoreline is about 35m. It is considered that the design should be the same as that of Phase I, except that the distance from the coastal road to the seawall (Section C-D in Figure 4.1.6) should be 20 m wide.

Figure 4-1.5 Present condition of east coast of Hulhumale' Island (Phase II)



Note 1: This proposed profile is for the initial study. The location of the sandy beach on the seaward side of the seawall is depicted based on the current sandy beach location, and the specifications of the structure should be determined after a detailed assessment of natural conditions.

Note 2: There was a request from HDC to make the height of the sandy beach on the landward side of the seawall the same as the height of the main body of the seawall +3.5m. This will require further study.

Figure 4-1.6 Proposed seawall plan of east coast of Hulhumale' Island (Phase II)

(3) Change of alignment (140m) and reinforcement (100m) of the existing seawall on the east coast of Male' Island

During the field survey, wave overtopping and flying sand was observed in a part of the east seawall of Male' Island (Seawall B indicated in Fig.4.1.7) completed in 1998 due to sand sedimentation. According to the Government of Maldives, the damage caused by overtopping and blowing sand was reduced by changing the seawall layout when the coastal road was widened, but overtopping and flying sand continues to occur and the Government was requested to take countermeasures. As a result of the initial study, changing the seawall face line slightly to the sea side and increasing the number of armor stones could be considered necessary. As this area is the only place where surfing is allowed around Male' Island, in determining the position of the seawall, it is necessary to consider the level of disaster risk and examine how constructed seawalls can mitigate disaster risks while maintaining the livelihood

and leisure of the citizens.

In addition, the seawall on the north side of the artificial beach (Seawall A indicated in Fig.4.1.7) is frequently overtopped by waves. In this area, it may be necessary to elevate the top of the existing seawall to +3.5 m and widening of the armor stones in consideration sea level rise. It is necessary to determine the specifications of the structure based on a more detailed investigation of the natural conditions and the current damage situation.

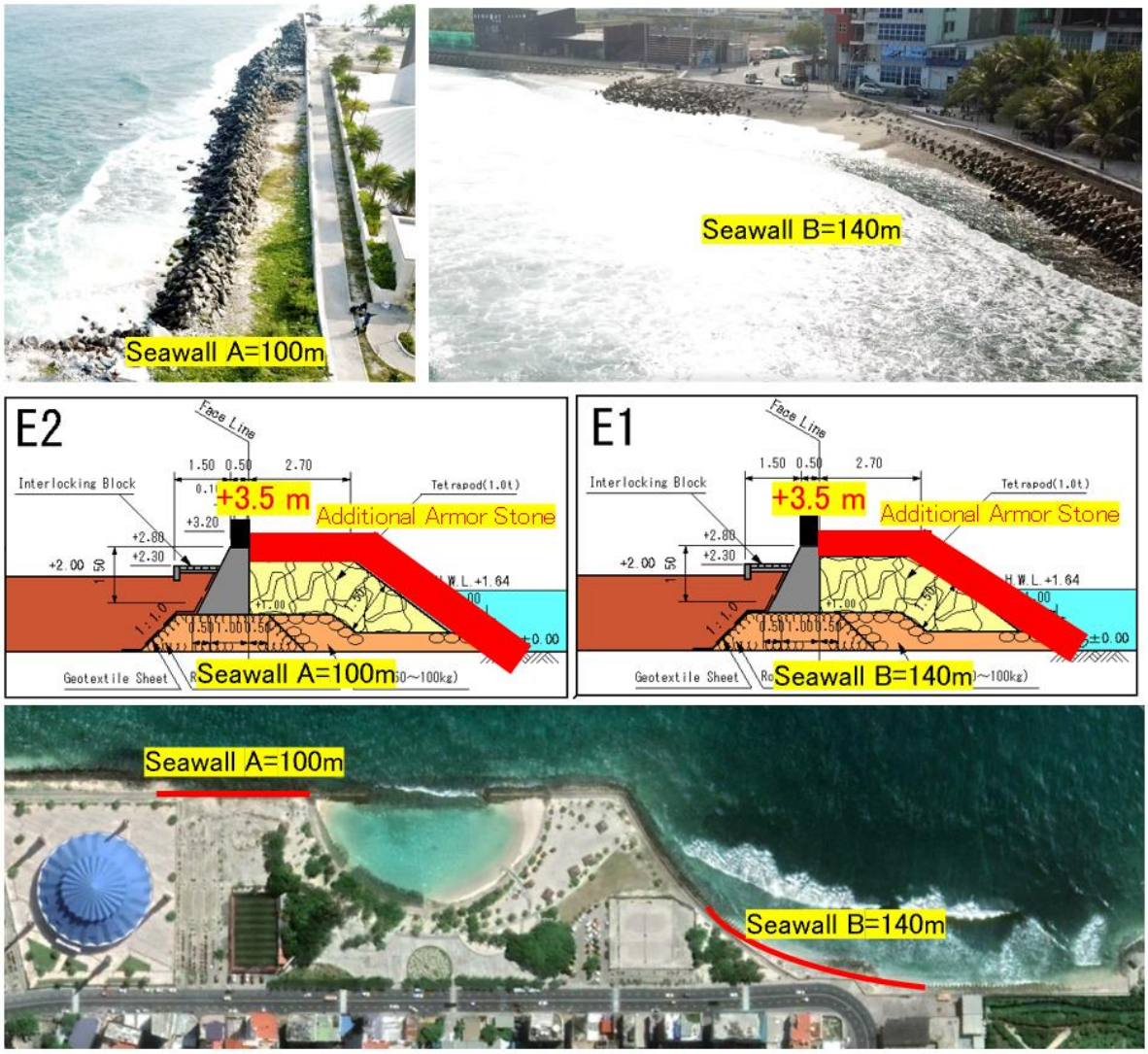
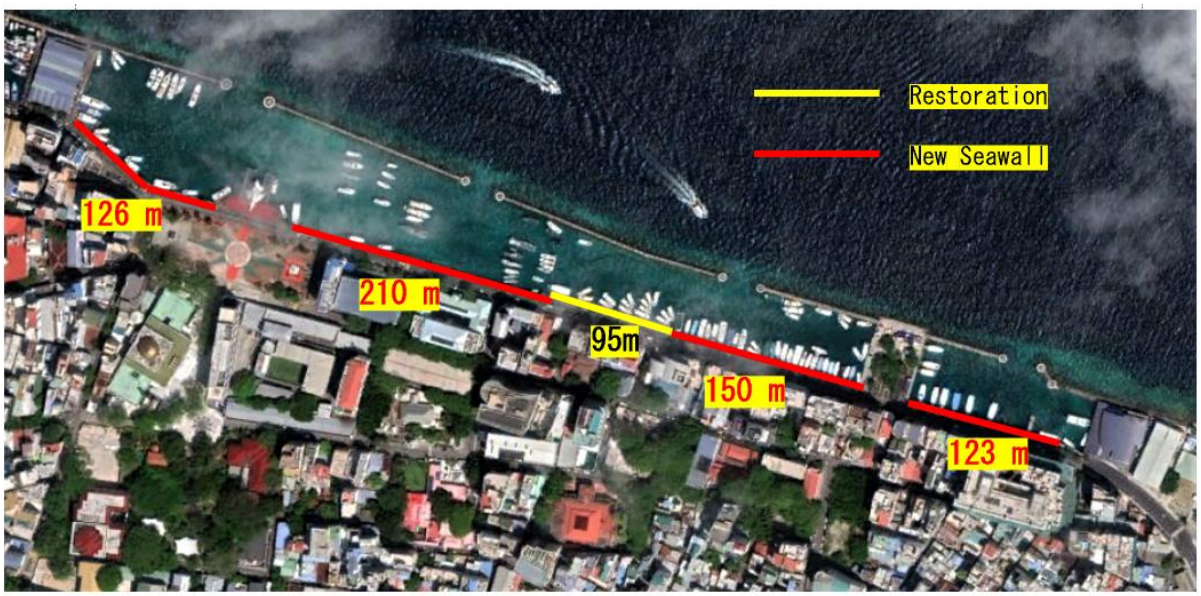


Figure 4-1.7 Present condition and proposed seawall plan of east coast of Male' Island

(4) Reinforcement of seawall on the north coast of Male' Island

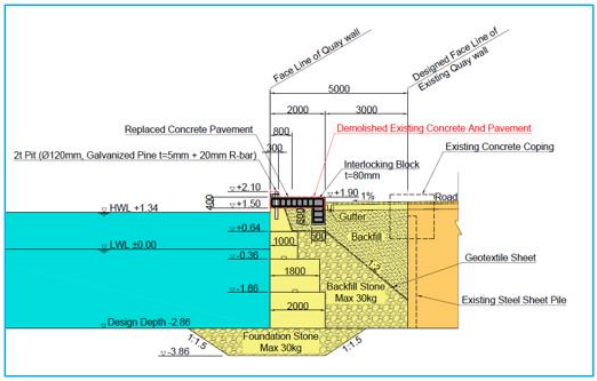
The seawall on the north coast of Male' Island was constructed with steel sheet piles in the 1980s, but partially collapsed when the 2004 tsunami hit, exceeding the design external force. The collapsed part was reconstructed as part of the "Maldives Tsunami Reconstruction Project" (Loan Agreement signed in July 2006). Considering the fact that the steel sheet piles (about 609m), apart from the section restored by the Yen Loan project, are also deteriorating rapidly, it is considered necessary to reinforce them at an early stage. In addition, the north coast road of the seawall is the busiest and most important road in Male', lined with the Presidential Palace, government offices, banks, airline companies, restaurants, etc. the Study Team proposes the following plan which includes seawall reinforcement as well as expansion of the road width. The specific design of the project will require further study based on surveying and ground investigation.

The following project idea also could adopt the same type of seawall structure as the one used in the Yen Loan project, and was designed to limit the width of the seawall to about 1.5 m to avoid narrowing the anchorage. It should be noted that, in the final stage of discussion with the Government of Maldives in this survey, the information about a new development plan of Male' north area came to light. The plan includes the road expansion of 5 m and future changes to the land usage of the north area. The need for reinforcement of seawall was confirmed during this survey; however, the below plan should be revisited once the information about the development plan is available.

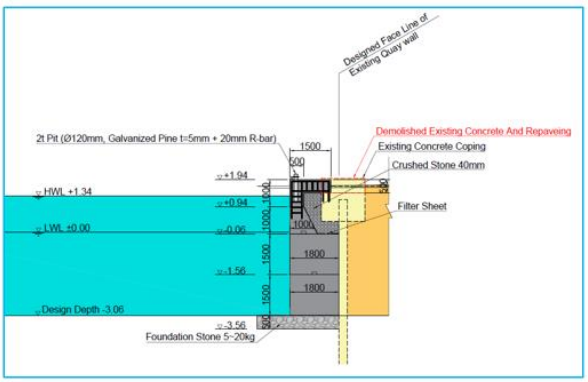


Location Map of the north seawalls of Male' Island

The north seawall used as a mooring area (L) and the busy coastal road (R)
(The right side of the photo on the left, partly overhanging the basin is the yellow line section on the map.)



Proposed restore plan (95 m, yellow area on the map).



Proposed reinforcement plan (609 m, red area on the map).

Figure 4-1.8 Present condition and proposed seawall plan of north coast of Male' Island

In addition to reinforcement of the seawall, the concrete blocks of the 95-meter seawall that was widened and reinforced in the Yen Loan project are partially displaced due to excessive towing force of ships. It is proposed that this part be repaired as shown in Figure 4.1.8. When reinforcing the seawall in the future, it is necessary to take into consideration the towing force of ships. In addition, because an important road passes through the north shore, it will be difficult to close the road for construction during the daytime, and night work is expected to be forced. Although it is not impossible to work from the sea, it will affect other vessels and will be expensive. The construction method and process need to be decided after thorough consultation with the Maldivian side.

4-2 Flooding

Proposed countermeasures for inland flooding are discussed for Male' Island and Hulhumale Island. Since the World Bank project is currently on-going, the following cooperation plans (1) and (2) would require close coordination with the World Bank.

(1) Stormwater drainage facilities on Male' Island

On Male' Island, WB is currently implementing a stormwater drainage improvement project as discussed in previous chapters. The WB project scope does not include equipping MWSC with operation management system of the existing pumps, such as SCADA system, which would increase the drainage capacity if implemented.

In addition, a need exists to provide the cleaning equipment since there is a concern that the cross-sections are clogged due to insufficient operation and maintenance (O&M) of the existing drainage gutters and pipes (e.g. improvement of gratings and cleanings). It is desirable to conduct capacity development training as well if and when these equipment is provided.

Table 4-2.1 Proposal of cooperation on inland flooding measures on Male' Island

Item	Contents
Identified Scope	(1) Introduction of monitoring system (SCADA system) for pump facilities (to MWSC) - To monitor the operation status of stormwater drainage pumps in 15 locations (2) Maintenance support for road drainage (to MCC) - Introduction of cleaning equipment (jet, vacuum), improvement of grating on road gutters - Cleaning activities, cleaning and maintenance plans for drainage facilities (road gutters using the above equipment, cleaning and maintenance manual
Counterpart Agency (O&M Regime and Budget Scale)	C/P Agency：(1) MWSC, (2) MCC Implementation Regime: (1) Introduction Training for MWSC staff by expert (2) Several MCC & RDC staff + 1 Expert Project Scale: Around JPY 300 million
Project Schedule	24 months
Consistency with national policies and plans for climate change and disaster risk reduction in the Maldives	Consistent with "Strategic Action Plan 2019-2023" since this project can contribute to disaster risk reduction
Medium- to long-term development effect when the proposed cooperation plan is realized	In order to contribute to the reduction of the degree and duration of inundation in Male' Island, it is possible to mitigate the suspension of socio-economic activities after heavy rainfalls.

Source: JICA Survey Team

(2) Identified cooperation by preparation of stormwater management plan for Hulhumale' Island

As for Hulhumale' Island, stormwater drainage facilities (pipes, drainage channels, pump facilities) have not been developed at this time, and the island relies on the underground infiltration capacity. In the future, more ground surface would be covered with pavement and buildings due to the progress of urbanization, and the infiltration area would decrease. It is considered necessary to prepare a comprehensive stormwater drainage master plan as a first step to address these issues, and the support in this field was also requested by HDC.

Table 4-2.2 Proposal of cooperation on inland flooding control on Hulhumale' Island (Master Plan)

Item	Contents
Proposed Scope	Contents of Stormwater Drainage Master Plan in Hulhumale Island (1) Preparation of topographic map in Hulhumale Island (S=1/1,000) (2) Study and assessment of underground infiltration capacity in Hulhumale Island (including investigation of existing rainwater penetration facilities) (3) Analysis of changes in rainfall intensity due to the effects of climate change (4) Confirmation of current development status/plans and proposals for improvement (5) Examination of the need for underground storage tanks (6) Introduction of applicable stormwater drainage, storage and infiltration technology (7) Study of effective utilization methods of stored rainwater on and under the ground (8) Stormwater drainage facility development plan (including zoning in connection with urban development plan, appropriate stormwater drainage, storage, and infiltration methods for each zone, stepwise development plan, stormwater runoff analysis before and after development) (9) Feasibility studies for priority zone and works (10) Preparation of operation & maintenance plan (11) Preliminary cost estimation (12) Preparation of preliminary construction plan / procurement plan (13) Study of organizational and institutional improvement (14) Environmental and social consideration (15) Enlightenment of public awareness
Counterpart Agency (O&M Regime and Budget Scale)	C/P Agency：HDC Implementation Regime：Some HDC Staff＋10 Experts Proposed Experts in the survey： Team Leader ／ Stormwater Drainage Plan ／ Drainage Network Analysis ／ Facility Design ／ Management and O&M Plan／Cost Estimate, Construction and Procurement Plan ／ Organization and Institution ／ Natural Condition Survey & Topographic Survey Supervision／Environmental and Social Consideration／Public Awareness Project Scale: Around JPY 200 million
Project Schedule	24 months
Consistency with national policies and plans for climate change and disaster risk reduction in the Maldives	Consistent with "Strategic Action Plan 2019-2023" because of contribution to disaster risk reduction
Medium- to long-term development effect when the proposed cooperation plan is realized	Even in the future when disaster risk increases due to climate change, safety against inland flooding in Hulhumale' will be guaranteed.

Source: JICA Survey Team

At the time of discussions with the Maldivian government agencies regarding the preparation of the Stormwater Drainage Master Plan (MP) for Hulhumale' Island, the following opinions were received.

1) HDC
- The need for MP preparation by the Japanese side is very high.
- It is estimated that the sea level rise due to future climate change will be around 50 cm by 2100.
- It is requested to investigate soil properties, land use, hydrological analysis, etc. and prepare an MP that includes not only drainage but also water use plans such as irrigation water and reservoirs. (need to be discussed)
- HDC has specialized staff in the fields of construction / urban planning and civil engineering in general, but does not have individual specialties such as drainage, water resources, and coasts. Since MNU does not have the content to educate engineers with such expertise, we would like to use it as an opportunity to train engineers.

2) MLSA
-There is no survey map, and it is useful for the Maldives to have the data for future development (Male' Island plans to create a 1/1000 topographic map for the WB project.

(3) Dispatching expert to the agencies in charge of stormwater drainage

As discussed in 3-2-3, the World Bank's MUDRP includes a component regarding stormwater drainage facilities in Male', and may also prepare stormwater drainage master plan in Hulhumale. Therefore, planning a new cooperation in the field of stormwater drainage will require close coordination with the WB. In the discussions held with relevant agencies, the survey team recognized a need for having an internal counsel at the relevant agencies for stormwater drainage planning, policymaking, and O&M of the facilities. Dispatching technical experts for this purpose will contribute to improve the countermeasures against inland flooding in the metropolitan region.

Table 4-2.3 Proposed work of stormwater management expert

Item	Contents
Identified Scope	- Advisory work for MNPHI and its staff in the field of stormwater drainage plan and policy for Male' Island - Advice on O&M of stormwater drainage facility to MWSC and MCC - Technical assistance to HDC staff in the preparation of stormwater drainage plans and O&M of existing infiltration facilities on Hulhumale' Island
Counterpart Agency (O&M Regime and Budget Scale)	C/P Agency: MNPHI Implementation Regime: : Staff of the above-mentioned related organizations, with MNPHI as the main counterpart, and one Japanese long-term expert Project Scale: Less than JPY 100 million
Applicability of Japanese Technology	If it precedes 1) and 2), it is possible to support the procurement and introduction of Japanese products.
Project Schedule	12 months
Consistency with national policies and plans for climate change and disaster risk reduction in the Maldives	Consistent with "Strategic Action Plan 2019-2023" since this project can contribute to disaster risk reduction
Medium- to long-term development effect when the proposed cooperation plan is realized	In order to contribute to the reduction of inundation and the time in Male' Island, it is possible to prevent the suspension of socio-economic activities after rainfall.

Source: JICA Survey Team

(4) Points to consider

The above three cooperation ideas are summarized below.

Table 4-2.4 List of corporation ideas for flooding measures

No.	Project Name (tentative)	Aid Scheme	C/P Agency	Prospectivity
1	Improvement of Operation and Maintenance Capacity for Stormwater Drainage Sector in Male' (*SCADA, equipment)	T/C	MWSC, MCC /MNPHI	Middle
2	Stormwater Drainage Master Plan Study for Hulhumale' Island	T/C	HDC	Middle
3	Dispatch of stormwater management expert	Dispatch of expert	MNPHI	High

Note: T/C = technical cooperation
Source: JICA Survey Team

1) Improvement of operation and maintenance capacity for stormwater drainage sector in Male'

The field staff of MWSC had opinions that it is inefficient to grasp the operating status of pumps one by one at multiple sites due to the lack of a monitoring and control system. Therefore, it can be said that the introduction of the SCADA system is an effective means of improving O&M works. In addition, as there is a shortage of cleaning equipment such as vacuum trucks and water jet trucks, considering the risk that the frequency of heavy rains would increase in the future and the emergency drainage capacity by the NDMA would be limited, for the need for maintaining drainage capacity by regular cleaning is high.

According to MNPHI, the ministry is possible to procure highly necessary materials and equipment with their budget. Therefore, it is possible to dispatch experts to MNPHI first and procure equipment with their own funds, depending on the urgency. Since flood damage is already severe and is expected to increase in the future, MNPHI has high expectations for support for Male' Island.

2) Stormwater drainage master plan study for Hulhumale' Island

The project by the World Bank may include the preparation of a master plan for Hulhumale Island; therefore, this plan would require close coordination with the WB. Hulhumale' Island is in the process of rapid development, and due to 1) the decrease in the area where infiltration to the underground is possible, 2) the forecasts of increase in heavy rainfall and the rising tide levels, the Island may experience large-scale inundation if heavy rainfall that continues for several hours occurs in the future. The need for a new master plan is confirmed, and the discussion with HDC, the relevant agencies in the Government of Maldives, and the World Bank should be continued.

3) Dispatch of stormwater management expert

As mentioned above, expectation by MNPHI is high and there is no direct overlap with the MUDRP by WB. Although it is possible to realize the project earlier than the other two proposed project ideas, it is necessary to pay attention to how the expert is involved in the preparation of the stormwater management master plan and the development of the drainage facilities in MUDRP, and it is important to cooperate with the WB as an advisor to the MHPHI and other related organizations. The expert is expected to contribute to the coordination and preparation of the above two projects between the Japanese side and the related organizations in Maldives, when it is realized.

4-3 Human Resource Development for Improved DRR Infrastructure Management

In order to develop, and maintain infrastructure for disaster risk reduction, it is important that the agencies in charge have the capacity to carry out appropriate planning, design, construction supervision, and operation and maintenance. To this end, the importance of improving the capacity of staff of the relevant agencies is high.

1) The staff of relevant agencies do not necessarily have expertise in coastal engineering or urban drainage; therefore, opportunities to learn basic knowledge on these areas can provided.

2) In terms of practical work, the following aspects should be strengthened: (i) guidance on planning and design of DRR infrastructure, (ii) understanding of problems and clarification of mechanisms occurring in practical work such as maintenance and management of existing infrastructure, (iii) periodic inspection of facilities and record keeping, (iv) patrolling and creation of image records in the events of disasters, and (v) creation of archives of technical materials such as design reports and as-built drawings. (i) ~ (iv) will be stipulated as planning / design / maintenance guidelines. This will strengthen the capacity of both the personnels and the agency.

These items are explained in the table below. The details of 2) above are explained in Appendix 7.

Table4-3.1 Strengthening the human resource capacity for DRR infrastructure

Overall goal
Development and maintenance of DRR infrastructure will be sustained.
Project purpose
The human and organizational capacity required for the development and maintenance of DRR infrastructure is strengthened.
Outputs
1. to acquire basic knowledge about planning, design and maintenance of DRR infrastructure 2. to understand the actual phenomena on the sites and to acquire practical skills for planning, design, and maintenance 3. to develop a design standard and a maintenance guideline
Activities
1-1 Learning and practice of basic knowledge on planning and design 1-2 Learning basic knowledge on maintenance 2-1 Learning the mechanism of actual phenomena on the sites, such as coastal erosion, inland flooding, / structural damage, and their countermeasures 2-2 Learning the operation and maintenance methods based on actual phenomena: inspection, record keeping, patrol, image recording, archiving of technical matters, etc. 3-1 Customization of Japanese guidelines / standards for application to the Maldives 3-2 Development of planning and design standards and maintenance manuals for coastal engineering and urban drainage in the Maldives Inputs include dispatch of experts and visiting Japan through technical cooperation.
Relevant agencies
The agencies related to DRR infrastructure such as MNPHI and HDC.

4-4 Practical Education and Research in Higher Education

The results of interviews to the relevant government agencies revealed that in order to counter the inland flooding and storm surges that are occurring in the metropolitan area, university students in the classes of hydraulics, hydrology, and coastal engineering need not only to know about the movement of water, waves, and sand, but also to have the knowledge to link this knowledge to disaster countermeasures. As a way to achieve this, the bachelor of civil engineering establishes a more practical education and research system.

Table4-4.1 Introduction of practical education and research in higher education

Overall goal
Human resources needed for the development and maintenance of DRR infrastructure are allocated properly.
Project purpose
Practical education and research system for coastal engineering and urban drainage are established at the MNU.
Outputs
1. Curriculum and materials for practical education/research on coastal engineering and urban drainage are developed at the bachelor of civil engineering in MNU 2. The faculties understand the application methodology of the developed curriculum and materials.
Activities
1-1 Dispatch of Japanese university faculties, research institute staff, and firm engineers specialized in the fields of coastal engineering and urban drainage 1-2 Creation of practical teaching/research materials and curricula to identify issues and solve problems actually occurring on the sites 2-1 Support for classes, exercises, researches and paper presentations: The target of support is faculty members, but students and government engineers participates in the classes, exercises and research activities. Credits are granted them on short-term intensive classes 2-2 Trainings in Japan for MNU faculty members and university staff

Secondary effects are expected:
(1) Medium and long term effects are expected as follows:
- It is assumed that the audience will acquire knowledge on coastal engineering and urban drainage through the research presentation. Such occasions of presentation may be held by the Maldivian Society of Civil Engineers.
- It is expected to raise awareness of DRR in the Maldivian society by inviting relevant ministry staff, senior officials, politicians, and general public to the presentations.

(2) In the short term, it is anticipated to improve the expertise of students and engineers who participate in the intensive classes with lectures and exercises.

4-5 DRR education in schools

(1) DRR Education in the Maldives

The 2004 Indian Ocean Tsunami caused enormous human and economic damage to the Maldives. This revealed the vulnerability of the low-altitude island nation to disasters. In addition, the National Adaptation Program of Action (2006) presented adaptation measures for disasters caused by climate change. In 2011, the Ministry of Education made it compulsory for each school to prepare a School Emergency Operation Plan (SEOP), and in 2018, DRR education was introduced into school education.[9)]

On the other hand, Japan has a long history of DRR education, as it has always been exposed to disasters. Lessons learned from the Meiji Sanriku-off shore Tsunami were published in a national elementary school textbook in 1937. The 1947 school curriculum made DRR a unit of social studies. Lessons learned from the Great Hanshin Earthquake in 1995 and the Great East Japan Earthquake in 2011 is shared in the DRR education[10)]. In comparison, the history of DRR education in the Maldives is much shorter, and it is still under progressing stage.

(2) Contents of proposed cooperation

The following provides overview of the proposal of a technical cooperation project.

[9)] Ministry of Education, Maldives Education Analysis, February 2019, pp. 31-32, 127.
[10)] Aiko Sakurai: A Preliminary Study on Disaster Risk Management Education in Japan, Journal of International Cooperation Studies, Vol. 20, No. 2 and 3 (2013.1) pp. 147-169.

Table4-5.1 DRR education in schools

Overall goal
Students' awareness of DRR is enhanced.
Project purpose
The capacity of teachers in providing DRR education is improved
Outputs
1. Study guideline, curriculum, textbooks and teachers guideline on DRR will be developed. 2. Teachers training for DRR is prepared.
Activities
1-1 Creation of the study guideline for school DRR 1-2 Creation of teachers guideline 1-3 Preparation of teaching materials 2-1 Preparation of scheme for teachers training 2-2 Training implementation 2-3 Revision of teachers training scheme based on DRR education implementation Input may include dispatch of experts, training in Japan for Maldivian personnels (MoE staff and school teachers)

(3) Content of the proposed study guideline and teachers guideline

1) The following points should be taken into account when developing the study guideline and teachers' guideline.

- As in the case of DRR education in Japan, evacuation procedures taking into account the unique location of the school, disaster history and topography is provided. It is more effective if hazard maps are incorporated.
- The rise in sea level due to climate change is expected to have a significant impact on life and economic activities in the metropolitan area. Under such circumstances, the opportunity to discuss issues unique to the island country should be provided by, for example, giving homework assignments to students as well as their parents to think about how their livelihood may change and what the country should be like in the future.
- The guideline may be developed for teachers to work with their students to address the issues. It is the role of school education to integrate the unprecedented experience of the tsunami and climate change preparedness into the curriculum and guide the children to a vision for their future[2)]. It is expected that teachers will be also incentivized to work on the issues with students.
- Japanese teaching materials of DRR education, educational methodology, what to do in the event of a disaster, how to promote DRR education in schools, case studies, etc., are used and customized to support the implementation of teachers training session.
- As a part of DRR education, the inclusion of items from the perspectives of the environment will enhance effectiveness of the education as explained the table below.

2） In Japan, the DRR education is specified in the study guideline by the Ministry of Education, Culture, Sports, Science and Technology (MEXT)[11)]. The subjects to be studied are defined according to the grade. The contents are divided among the subjects. It is comprehensive, specific, and practical (see the table below). The teachers' guideline have been developed by each local government. The guidelines are based on the unique natural / social environment and disaster history of each municipality.[12)]

When study guideline, teaching materials and the teachers' guideline are developed in the Maldives, these Japanese materials may be customized.

[11)] Cabinet Office Working Group on Public Awareness of Disaster Mitigation Education, Disaster Mitigation Education in Schools (Disaster Mitigation Education in Teaching Curriculum and Teacher Training. December 18, 2020, Document 3, http://www.bousai.go.jp/kaigirep/pdf/201218_03.pdf

[12)] Disaster Prevention Education Training in Initial Teacher Training in Wakayama Prefecture http://www.manabi.wakayama-c.ed.jp/kenkyukiyo/H23/H23/H23-6.pdf

Table4-5.2 DRR education by the Study Guideline of MEXT of Japan [3)]

Elementary School

Study Guideline 2017

Science, Grade 5

Student learn the velocity and volume of flowing water changes depending on how it rains, and the flooding can change the appearance of the land.

The function of flowing water

Social studies, Grade 5

Students understand that disasters occur in relation to the natural conditions of the land, and that the national and prefectural governments are implementing various measures and projects to protect the land from disasters and to protect people's lives.

Junior high school

Study Guideline 2017

Social studies

Students will be able to understand Japan's landforms, climate, and oceanic features, as well as disasters and efforts to prevent them. With this knowledge, students will be able to understand the characteristics of Japan's natural environment.

Joint evacuation drill of elementary and junior high schools

Science

- Students study the blessings of nature and volcanic and seismic hazards. They understand these in relation to volcanic activity and the mechanism of earthquake occurrence.
- Students investigate the blessings and disasters brought about by weather phenomena. They understand these in relation to changes in the climate of Japan.

Health and Physical Education (2nd grade of junior high school)

Students study the knowledge of first aid and injury prevention.

Senior high school

Study Guideline 2018

Comprehensive geography

- Students will learn about disasters found in Japan and other parts of the world, as well as disasters found in their own living areas.
- Students will learn about the characteristics of the local natural environment and how to prepare for and respond to disasters.
- Students will understand the scale and frequency of disasters and the importance of preparing for and responding to them based on local characteristics.
- Students acquire geographical skills to collect, read, and summarize various geographical information including hazard maps and old / new topographical maps for various disasters.
- Students understand the relationship between natural / social conditions, regional commonalities / differences, and sustainable regional development in terms of DRR based on regional characteristics.
- Students will examine and express preparedness and response to disasters from multiple perspectives.

Making of hazard map

(4) Secondary effects of DRR education

It is expected that the awareness towards DRR of students will influence their families and neighbors, which will in turn spread the awareness of DRR throughout the society and form public opinion. This is expected to further influence politicians and national policy, and facilitate the development of the necessary budget and systems, leading to disaster risk reduction, DRR. The development of capacity of teachers, which is the goal of this project, is important as one of the processes in the time frame needed to achieve the purpose mentioned

Appendix

Appendix1 Hazard Risk Map

The multihazard risk atlas of Maldives is developed by Ministry of Environment under the Asian Development Bank's regional knowledge and support. The atlas consists of five volume i.e., Volume I–Geography, Volume II–Climate and Geophysical Hazards, Volume III–Economy and Demographics, Volume IV–Biodiversity, and Volume V–Summary. The atlas provides spatial information and thematic maps required for assessing future development investments in terms of climate risks and geophysical hazards. The maps also aimed to support the climate change adaptation and disaster risk reduction.[13)]

The maps in this atlas are including seasonal and annual rainfall, temperature, population, education, health, tourism, transportation, etc. In Volume IV–Biodiversity, the islands with coastal protection, coastal erosion, coral bleaching risk, hydro-meteorological multihazards, rain-induced flood, tsunami hazard, etc. are mapped[14)]. However, the maps are not very detailed as shown in the example map below.

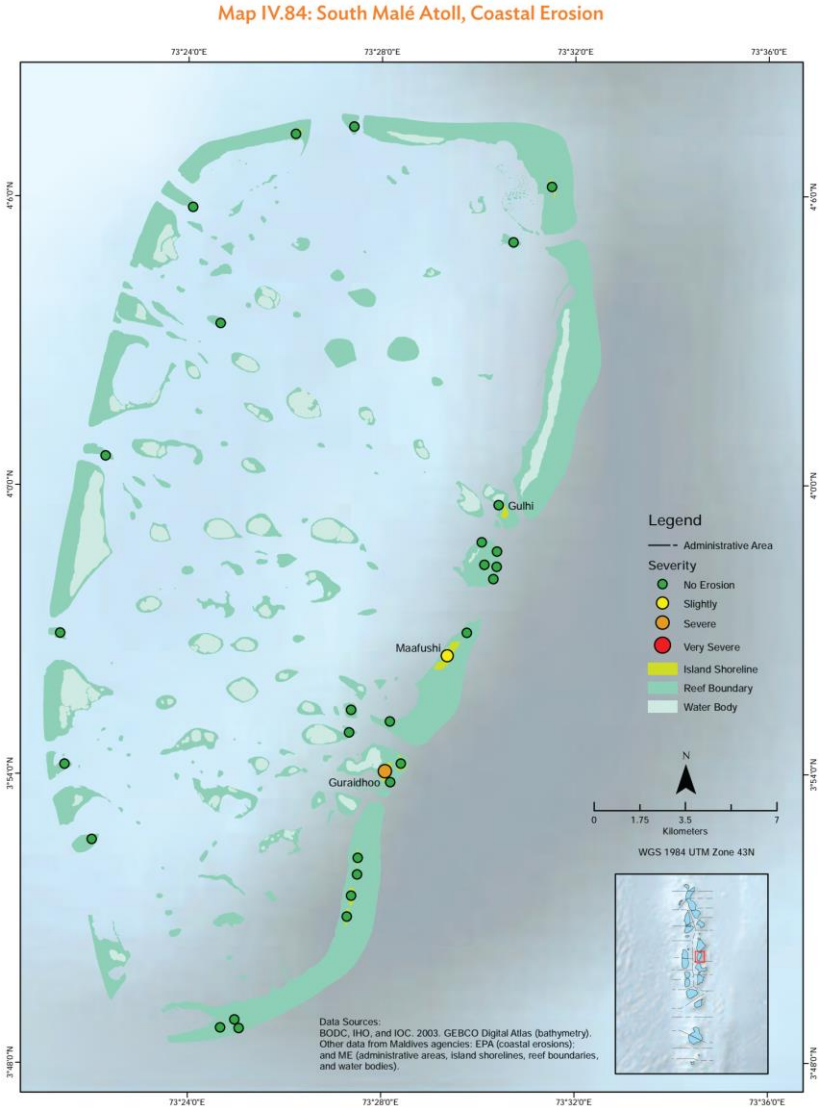


Figure 1. Example of the coastal erosion map in the atlas[14)]

[13)] Ministry of Environment, Climate Change and Technology, 2020, Multihazard Risk Atlas of Maldives, https://www.environment.gov.mv/v2/en/download/10458

[14)] Asian Development Bank, 2020, Multihazard Risk Atlas of Maldives Biodiversity – Volume IV, https://www.environment.gov.mv/v2/wp-content/files/publications/20200914-pub-maldives-multihazard-risk-atlas-vol4_2.pdf

Appendix2 Issues faced by MECCT

1. Issue of waste management:

On page 42 of the annual report (2019) of MECCT, it states that in many islands the waste in the landfills is not disposed properly. So, the bottles, tins and other wastes collect water and become breeding grounds for mosquitoes which may lead to diseases carried by mosquitoes. It is mentioned in the report that a system to dispose of this waste is under preparation.

In Minister Aminath Shauna's Statement on World Environment Day 2021 (05/06/21), she mentioned that marine pollution due to improper waste disposal was a concerning issue. She mentioned that proper waste management was necessary to avoid the negative effects that was caused due to marine pollution.

(Retrieved from http://www.environment.gov.mv/v2/en/download/11839)

2. Issue of soil/beach erosion and climate changes:

On page 18 of the annual report (2019), it states that the ministry often receives complaints from the public that beach erosion in the monsoons may cause damage to their property.

In minister's statement on World environment day 2021, she also mentioned that results of climate change and global warming, such as bleaching of corals and storm surges are a constant problem that the country is facing.

3. Issue related to research on Climate Change:

In the climate-change research strategy document (2015), it has been written that climate-change studies specific to Maldives are very limited, especially adaptation and mitigation research. Research capacity is limited in most agencies involved in climate change research and there does not seem to be an organized financing mechanism for research activities in the Maldives. Policy makers and planners often do not systematically use new research to guide their decisions, and legislative framework to maintain and regulate research is also weak.

(Ministry of Environment and Energy. (2015). *National climate change research strategy*. Retrieved from http://www.environment.gov.mv/v2/wp-content/files/publications/20211201-pub-nat-climate-change-research-strategy.pdf)

Appendix3 Disaster Emergency Response in Maldives

1. Emergency Response

The National Disaster Management Authority (NDMA), previously known as the National Disaster Management Center (NDMC), is the lead coordinating authority for disasters and emergency response. This authority is supported by the Maldives National Defense Force (MNDF), Maldives Police Service (MPS), and Maldivian Red Crescent (MRC). However, local administrations are the first line of response at the atoll and island levels.[15)]

Twenty administrative atolls and three city councils exist across 186 administrative islands of Maldives. Local councils (atolls, islands, and cities) are responsible for immediate response in cases of emergency in their jurisdiction[15]. If a disaster occurs in a city, atoll, or island, the city mayor, council president, or leader in charge of the island will lead the emergency response with local stakeholders[15]. The emergency response coordination is presented in Figure 1, while Figure 2 presents the institutional arrangement for emergency response.

The CERT (Community Emergency Response Team) are the first responder on each island/atoll in case of emergency. The team consists of 15-20 personnel of local volunteers who are trained by MRC, MNDF, MNDF's fire service and coast guard, and the police to handle emergency situations during the initial stages of disaster response[15]. These volunteers are educated about disaster preparedness and disaster response skills for the hazard that may affect their area such as safety, light search and rescue, team organization, and disaster medical operation[16)].

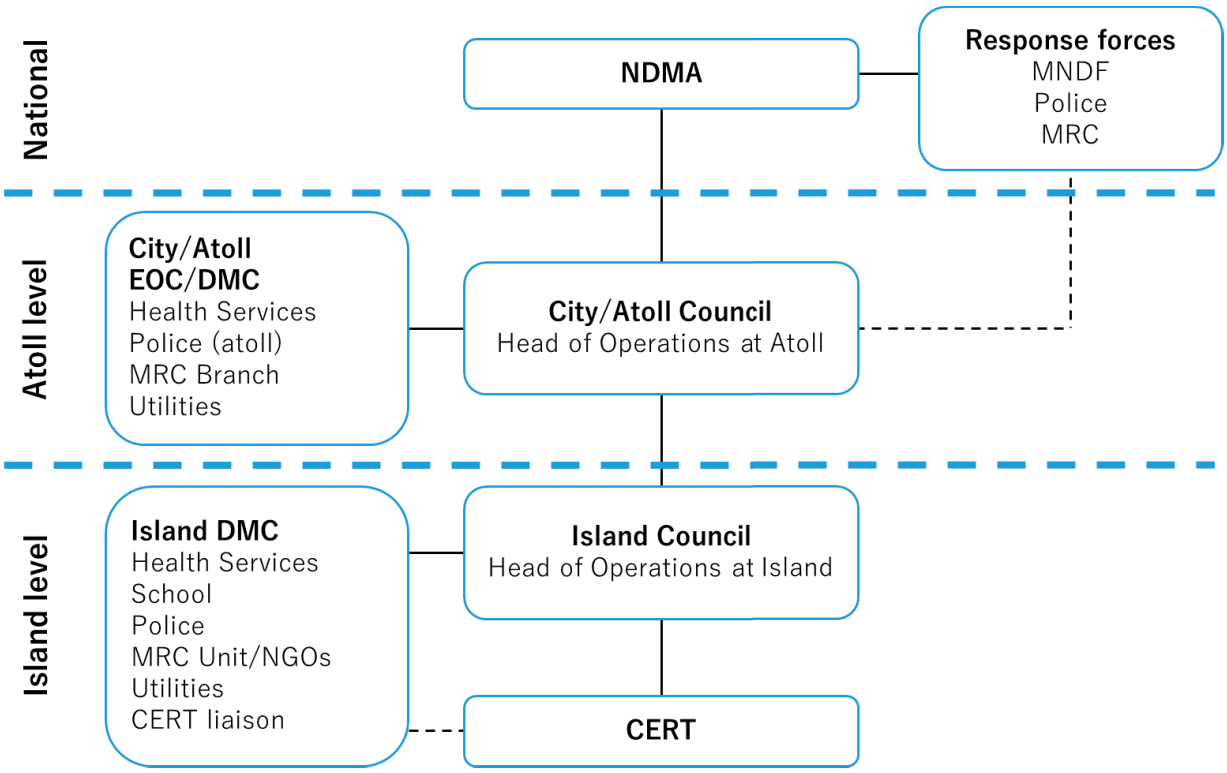


Figure 1. Emergency Response Coordination of Maldives[15)]

[15)] Center for Excellence in Disaster Management & Humanitarian Assistance, 2021, Maldives Disaster Management Reference Handbook, https://reliefweb.int/sites/reliefweb.int/files/resources/disaster-mgmt-ref-hdbk-Maldives2021.pdf
[16)] PSM News, 2018, NDMC begins establishing CERT teams across Maldives, https://psmnews.mv/en/34057

	Decision Making/Strategic	Emergency Management/Tactics	Field-level First Responders/Field Operations
National	NDMC Disaster Management Steering Committee	NDMC National Emergency Operations Centre	National Emergency Response Force (NERF)
Atoll/City	Atoll/City Disaster Management Committee	Atoll/City Disaster Management Committee	(a team will be created at this level when needed, using neighbouring islands (CERT))
Island/Local level	Islands Disaster Management Committee	Islands Disaster Management Committee	Community Emergency Response Team (CERT)

Figure 2. Institutional arrangements for emergency response[17)]

2. Information dissemination

The main agencies responsible for information, warning, and alerts are the Maldives Meteorological Service (MMS) and the National Disaster Management Authority (NDMA). MMS is the technical agency responsible for issuing early warnings related to most natural disasters. After receiving alerts from its own facilities or from regional and international agencies, MMC notifies NDMA, which is responsible for coordinating early warning and ensuring public dissemination[15]. The alert dissemination is presented in Figure 3. Maldives Meteorological Service (MMS) Meteorological Warning run on a scale of minor (white), moderate (yellow), severe (orange), and extreme (red) [15)] as illustrated in Table 1.

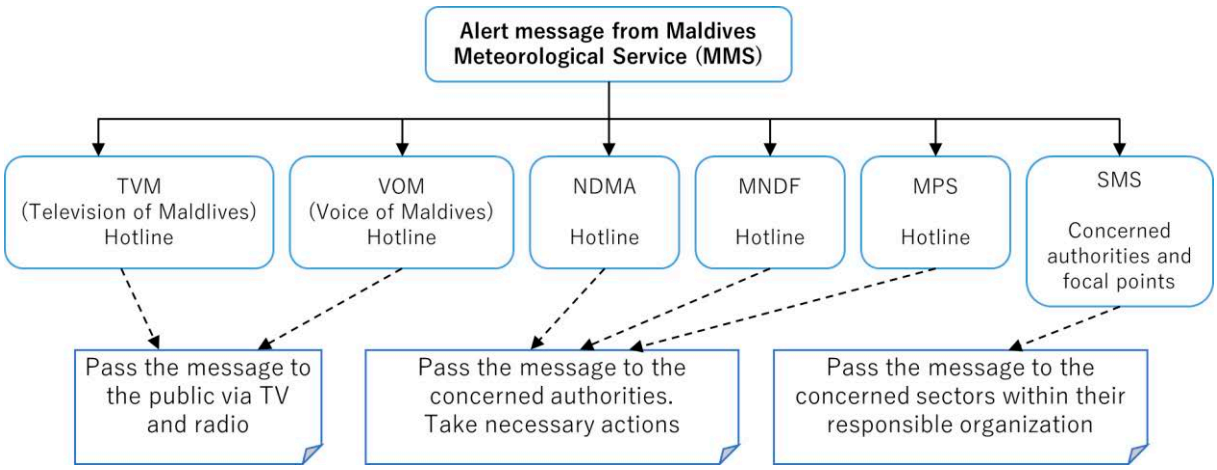


Figure 3. Flow chart of weather advisories and warnings[18)]

[17] Asian Disaster Reduction Centre, 2018, Republic of Maldives - Country Report, https://www.adrc.asia/countryreport/MDV/2018/Maldives_CR2018A.pdf

[18] Maldives Meteorological Service, 2017, Management of Maldives Meteorological Service, https://slidep layer.com/slide/13175957/

Table 1. Criteria for meteorological alerts and warnings[15)]

Hazard	Category of Severity			
	Minor (Alert level 1, WHITE)	**Moderate (Alert level 2, YELLOW)**	**Severe (Alert level 3, ORANGE)**	**Extreme (Alert level 3, RED)**
Heavy Rain and Flood	50 mm in 1hrs or 80 mm in 6 hours	70 mm in 1hrs or 100 mm in 6 hours	90 mm in 1hrs or 120 mm in 6 hours	180 mm in 6 hours
Thunderstorms (TS)	Significant TS reported and evident from satellite/Radar LDN	Moderate TS observed or evident from satellite/Radar/LDN	Severe TS observed or evident from satellite/ Radar/LDN	-
Wind and Seas	19-24 mph (past 3 hrs) or 22 – 27 mph (past 1hr), or forecast to meet this condition	25-30 mph (past 3 hrs) or 28 – 35 mph (past 1hr), or forecast to meet this condition	34-40 mph (past 3 hrs) or 36 – 42 mph (past 1hr), or forecast to meet this condition	>40 mph (past 3 hrs) or >42 mph (past 1hr), or forecast to meet this condition
Squalls (Frequent Gust)	50 - 54 mph	55 - 62 mph	63 - 69 mph	above 70 mph
Swell & Tidal Waves (observed or forecast)	Observed or forecast (minor impact)	Observed or forecast (affect at least 5 islands)	Observed or forecast (affect at least 10 islands)	Observed or forecast (extreme impact based)
Tropical Cyclone (TC)	RSMC declare TC center in the box within lat' S5-N12, lon' E66-E81	TC track towards Maldives and expect to cross Maldives atolls in next 24hr	TC track towards Maldives and expect to cross Maldives atolls in next 12hr	TC track towards Maldives and expect to cross Maldives atolls in next 6hr
Earthquake occurred	Magnitude >6 within 400km of Maldives EEZ. Or mag>7 in Indian Ocean within 4000km of Maldives EEZ	Magnitude >7 within 400km of Maldives EEZ. Or mag>8 in Indian Ocean within 4000km of Maldives EEZ	Magnitude > 8 within 400km of Maldives EEZ. Or mag>9 in Indian Ocean within 4000km of Maldives EEZ	Magnitude >9 within 400km of Maldives EEZ
Tsunami	Magnitude >8 in Indian Ocean within 4000km of Maldives EEZ. Or confirmation of Indian ocean wide Tsunami of low impact to Maldives	Magnitude>9 in Indian Ocean within 4000km of Maldives EEZ. Or confirmation of Indian ocean wide Tsunami of moderate impact to Maldives	Confirmation of Indian ocean wide Tsunami of high impact to Maldives	Confirmation of Indian ocean wide Tsunami of extreme impact to Maldives

Appendix4 Bachelor of Civil Engineering, Faculty of Engineering, Science and Technology, MNU

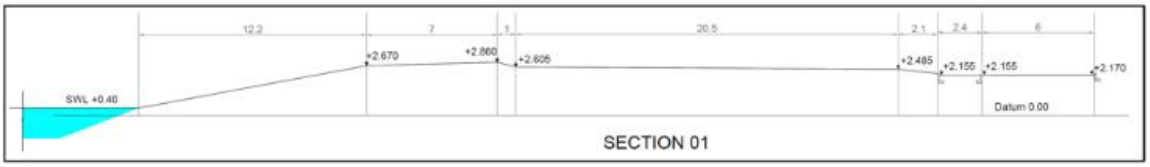
FACULTY OF ENGINEERING, SCIENCE AND TECHNOLOGY
BACHELOR OF CIVIL ENGINEERING

No.	SUBJECT
CPT137	COMPUTING FOR ENGINEERS
MAT123	ENGINEERING MATHEMATICS I
CHE107	MATERIAL SCIENCE & CHEMISTRY
ENG015	ENGLISH FOR ACADEMIC PURPOSES
PHY111	PHYSICS FOR ENGINEERS
BES101	BUILDING MATERIALS
BES105	CONSTRUCTION I
BES109	DRAWING AND SETTING OUT
MAT125	ENGINEERING MATHEMATICS II
PHY105	STATICS
MGT129	BASIC MANAGEMENT & MARKETING
BES107	CONSTRUCTION II
MAT127	ENGINEERING MATHEMATICS III
BES215	LAND SURVEYING I
PHY109	MECHANICS OF SOLIDS
BES103	BUILDING SERVICES I
BES249	CONSTRUCTION PROJECT MANAGEMENT
BES319	STATISTICS FOR ENGINEERS
BES305	LAND SURVEYING II
BES227	STRUCTURAL ANALYSIS
BES325	ENGINEERING COMPUTATIONS
BES323	GEOTECHNICAL ENGINEERING
BES203	CONSTRUCTION III
BES321	HYDRAULICS
BES229	STRUCTURAL DESIGN I
BES331	ENGINEERING PROJECT I
BES327	HYDROLOGY
BES335	BUILDING SERVICES II
BES329	STRUCTURAL DESIGN II
BES333	WATER & WASTE WATER ENGINEERING
BES401	ENGINEERING PROJECT II
BES407	ESTIMATING AND CONTRACTING
BES405	SUSTAINABLE TRANSPORT & HIGHWAY ENGINEERING
BES409	COASTAL ENGINEERING
LAW017	GENERAL PRINCIPLES OF LAW 1
BES403,	BES411 HONOURS THESIS I & THESIS II
DHI113	DHIVEHI FOR PROFESSIONALS

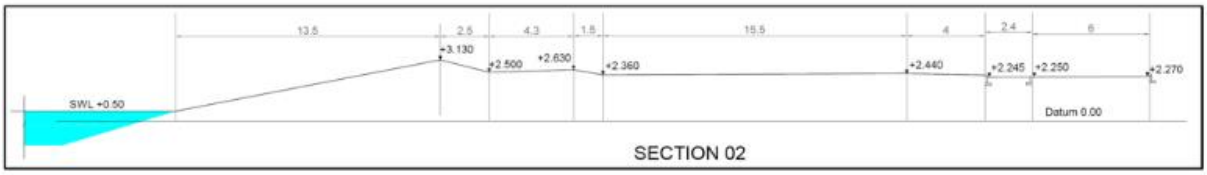
Source: Subject outlines 2014, Bachelor of Civil Engineering, Faculty of Engineering Technology, The Maldives National University

Appendix5 Preliminary Survey Result on the East Coast of Hulhumale Island

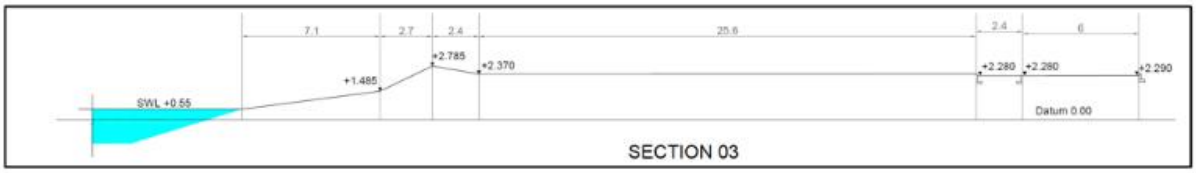
Location Map of Survey at East Coast of Hulhumale



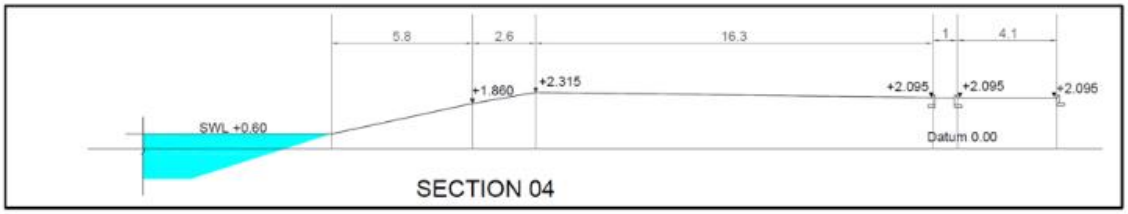
SECTION 01



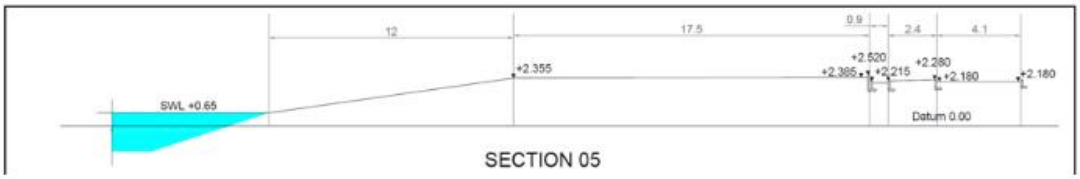
SECTION 02



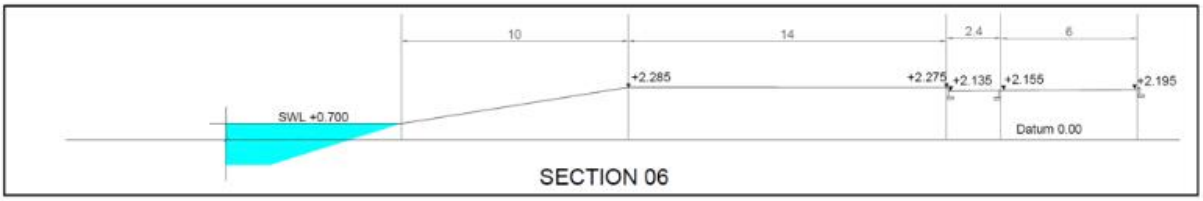
SECTION 03



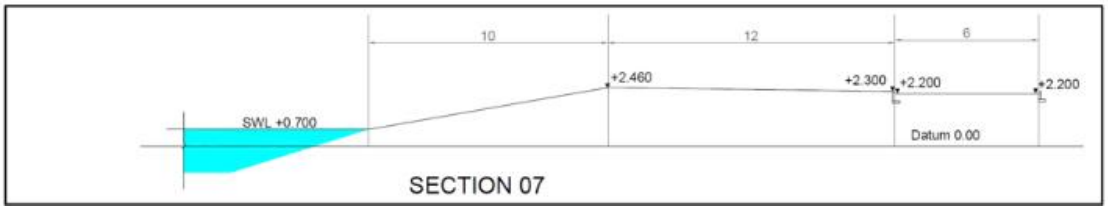
SECTION 04



SECTION 05



SECTION 06



SECTION 07

Appendix6 East Coast of Hulhumale Island

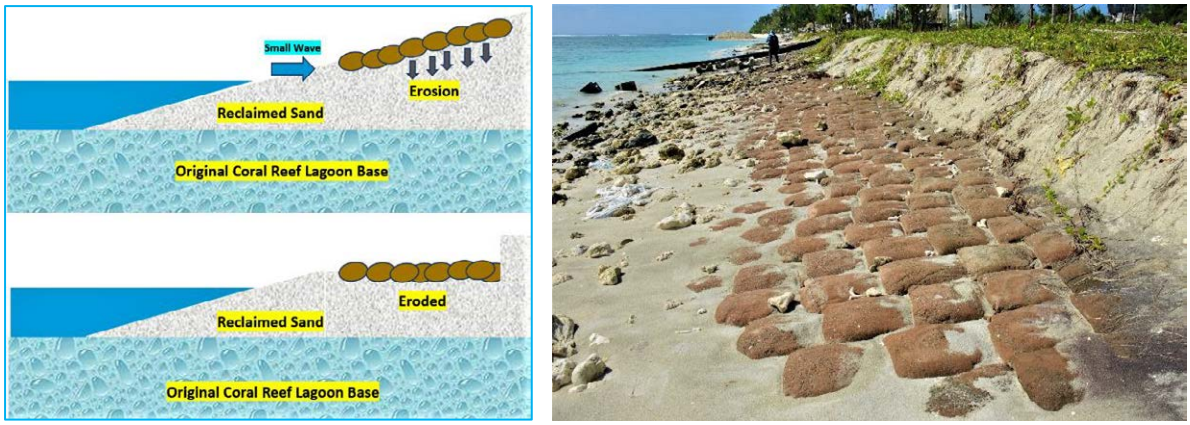
Note: This proposed profile is for the initial study. The location of the sandy beach on the seaward side of the seawall is depicted based on the current sandy beach location, and the specifications of the structure should be determined after a detailed assessment of natural conditions.

Figure 1. Construction plan of the east coast of Hulhumale Island (for reference)

Appendix7 Strengthening Practical Capacity on Disaster Prevention Infrastructure

It is important to keep an accurate grasp of the current status of coastal disaster prevention facilities in order to minimize damage to the facilities. For this purpose, it is recommended to carry out the following tasks on a daily basis.

1) Retain design reports, survey drawings, digital as-built drawings and copies for maintenance and future planning.
2) Regularly check the condition of the premises (organise digital photographs, record the location, date and time, explain the need for restoration, etc.)
3) Record videos of wave conditions and overtopping near the seawall during relatively large waves (add location, date and time, and description)
4) Where erosion of the beach is observed, study the mechanism of the cause of erosion and take measures accordingly. For example, if cement bags are simply placed on the beach on the east coast of Hulhumale Island, the sand under the bags will be washed away, as shown in the figure below. The bags need to be placed into hard layer.



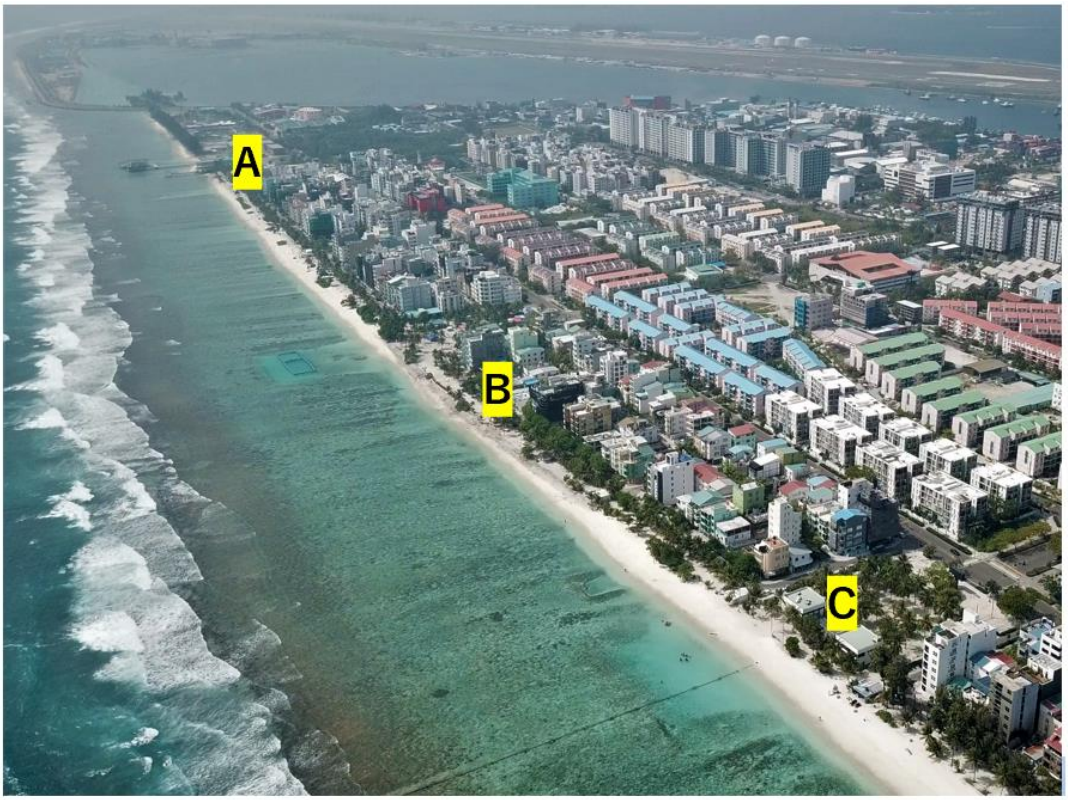
Cement bags were installed to intend to protect beach erosion from small waves. However, because no foundations were provided, the bags easily collapse and the beach sand is easily eroded. It is important to set foundation on the original coral reef lagoon base for this type of structure.

5) For the reparation and updating of coastal area use maps and coastal management, drones are a very effective tool. It is important that they are regularly photographed and organized so that the date, time and location are known.

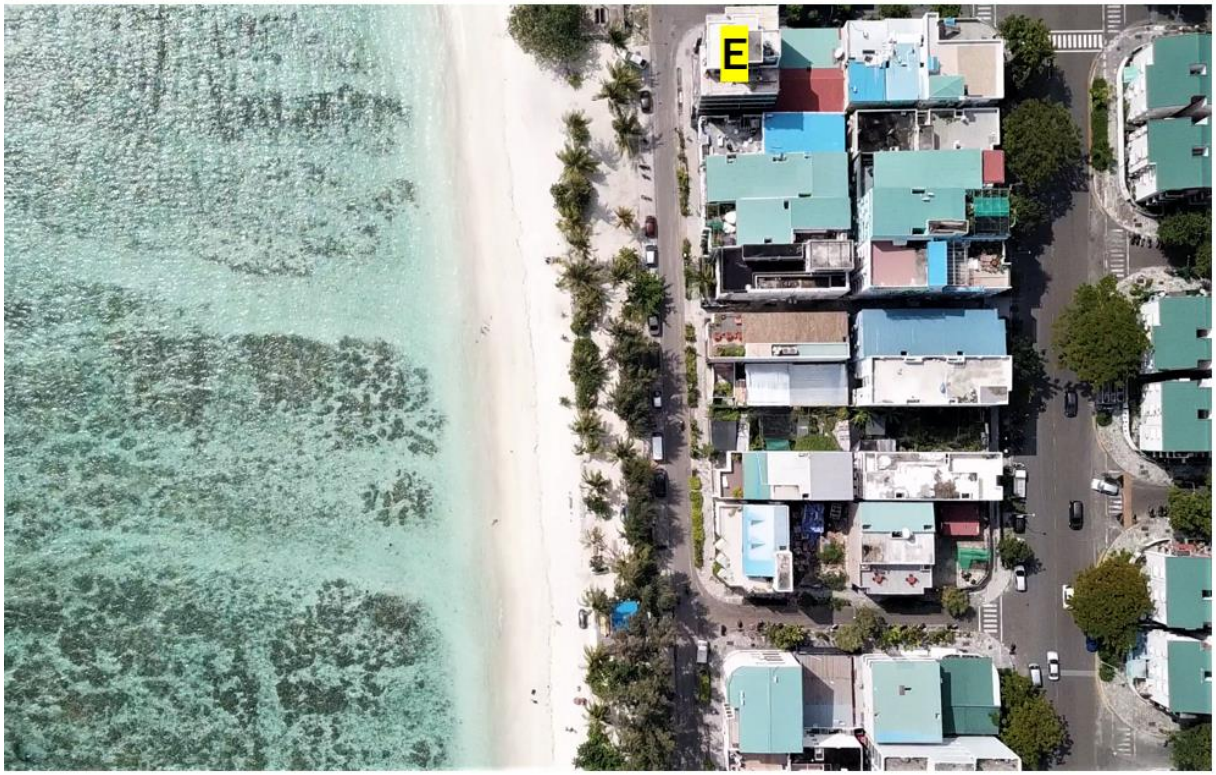
Appendix8 Photos of Hulhumale Island (As of Dec.2021)

Note: The same letter indicates the same place.

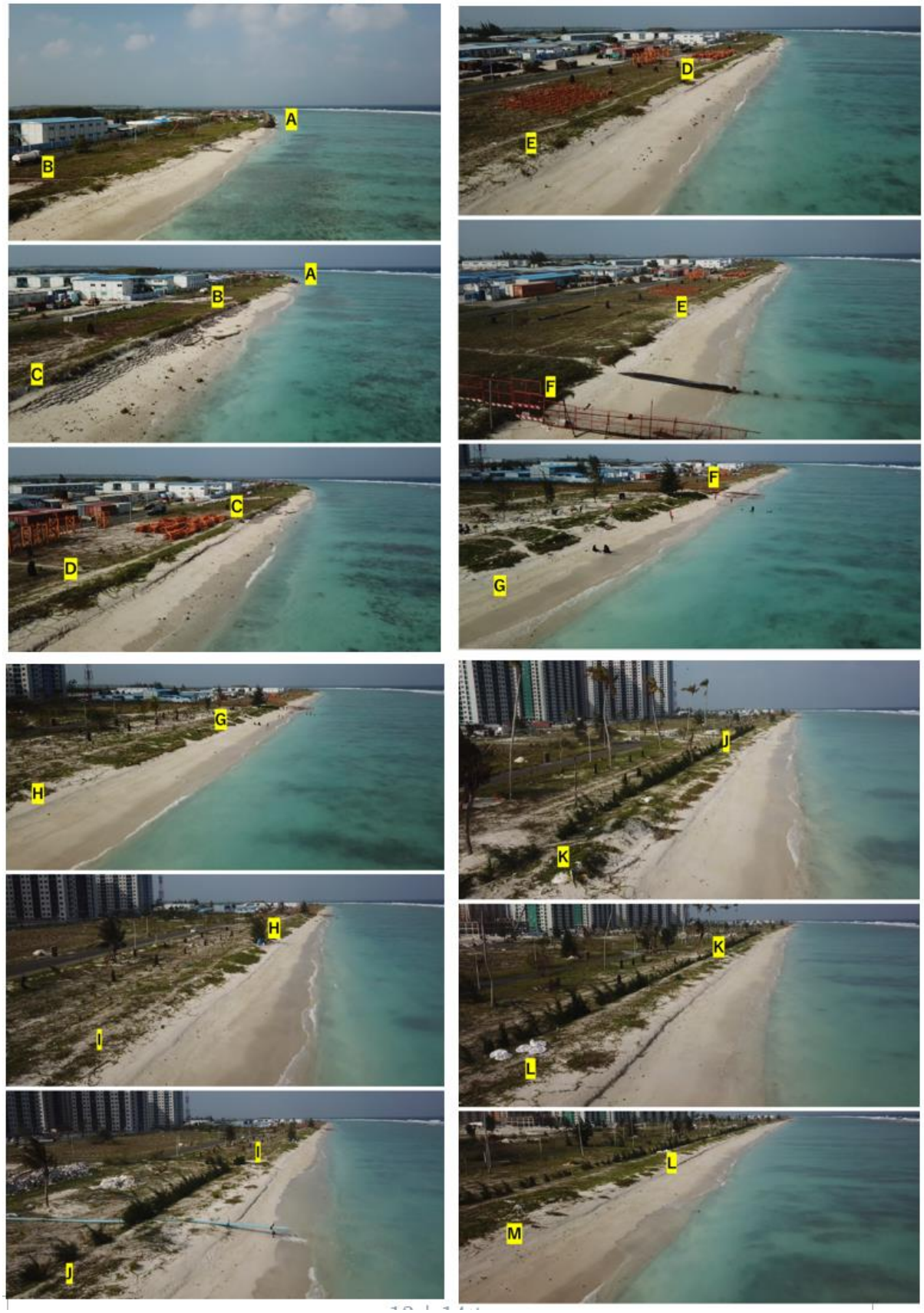
East coast of Hulhumale Island (Phase I)-1



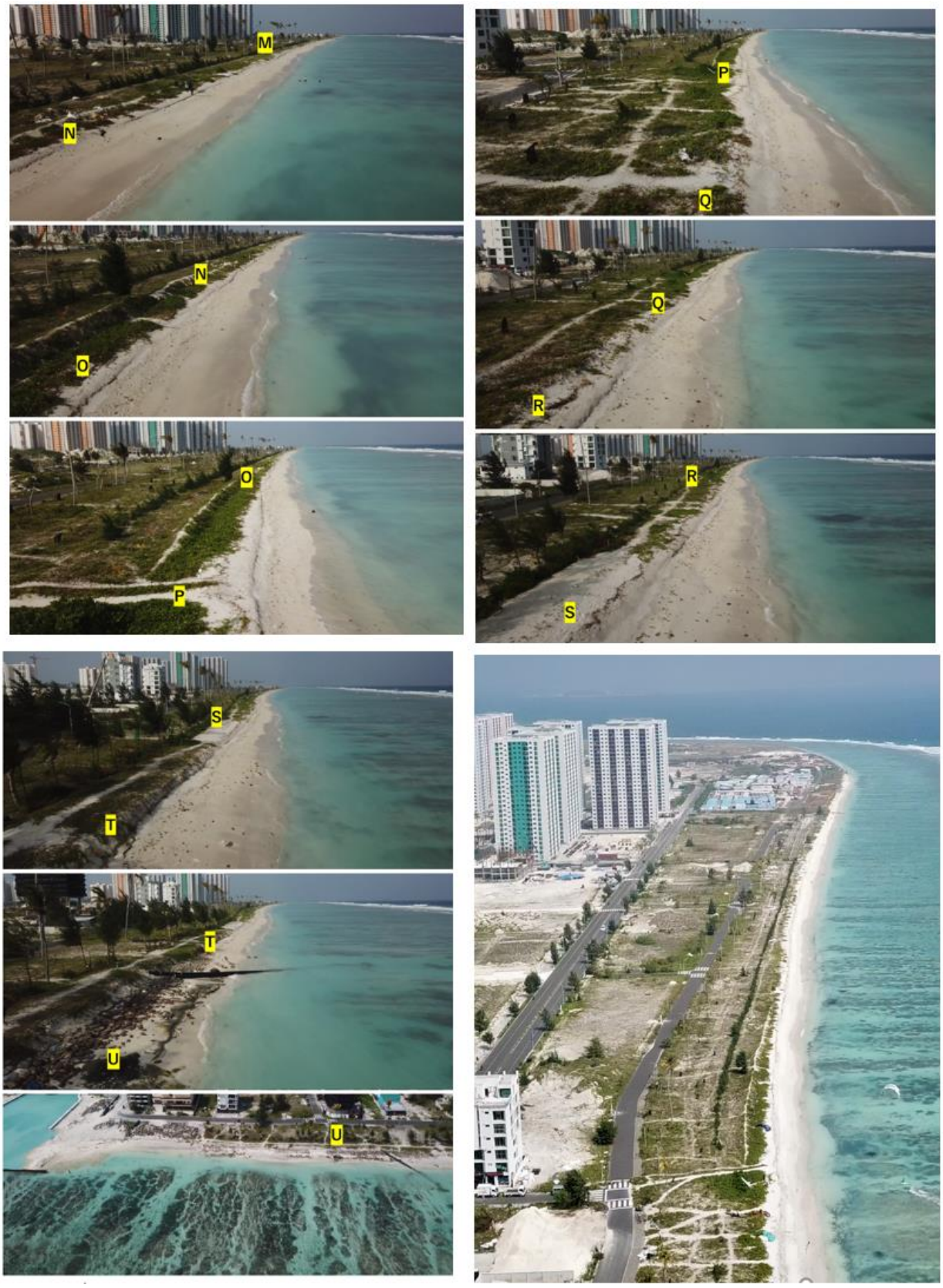
1. East coast of Hulhumale Island (Phase I)-2



2. East coast of Hulhumale Island (Phase Ⅱ) -1



3. East coast of Hulhumale Island (Phase Ⅱ)-2



Appendix9 Survey Team

Name	Assigned field	Work in Maldives 1st period
Junji YOKOKURA	Team Leader DRR planning Policy and Organization	Dec. 2~Dec. 25, 2021
Sadao ORISHIMO	Coastal Disaster	Dec. 2~Dec. 25, 2021
Yoshihiro TAKAMURA	Flood and Drainage	Dec.2, 2021~Jan. 3, 2022
Moeko KANNO	Assistant to Team Leader DRR planning Policy and Organization	Dec. 2~Dec. 25, 2021

Appendix10 Schedule at Maldives

		Team Leader / DRR planning / Policy and Organization	Coastal Disaster Risk Reduction/Coastal Zone Management	Flood Control/Inland Flooding Management	Assistant to Team Leader / DRR planning / Policy and Organization
		Junji YOKOKURA	Sadao ORISHIMO	Yoshihiro TAKAMURA	Moeko KANNO
02/12/21	Thu	UL0455, NRT, 11:20 - Ul103, CMB, 18:50 -MLE, 19:45			
03/12/21	Fri	Site survey on seawalls and coasts of Male'' Island			
04/12/21	Sat	Site survey on seawalls and coasts of Hulhumale Island			
05/12/21	Sun	Report at JICA Maldives Office, Meeting at MNPHI, Meeting at MECCT			
06/12/21	Mon	Site survey at Male' drain facility			
07/12/21	Tue	Site survey at Hulhumale, Data collection on web sites	Profile survey at Hulhumale coast	Site survey at Hulhumale, Data collection on web sites	
08/12/21	Wed	Meeting at HDC, Meeting at MWSC			
09/12/21	Thu	Meeting at MNPHI			
10/12/21	Fri	Checking the current status of coastal facilities from the sea on a boat (Male' Island, Hulhumale Island)			
11/12/21	Sat	Observation of the inland flooding in Male' Island after heavy rain			
12/12/21	Sun	Meeting at HDC, Meeting at MMS			
13/12/21	Mon	Data collection, report making	Data collection, report making	The Data Collection Survey on the Possibility of Assistance utilizing Okinawa's Resources in Environmental Sector in Maldives (QCBS)	Data collection, report making
14/12/21	Tue	Meeting at NDMA, Meeting with Mr. Ismail Ibraham(President of Maldives Association of Civil Engineers			Meeting at NDMA, Meeting with Mr. Ismail Ibraha: President of Maldives Association of Civil Engineers
15/12/21	Wed	Data collection, report making	Observation of the east beach on a jet boat at Hulhumale		Data collection, report making
16/12/21	Thu	Meeting at MNU			Meeting at MNU
17/12/21	Fri	Data collection, report making	Data collection, report making		Data collection, report making
18/12/21	Sat	Data collection, report making	Data collection, report making		Data collection, report making
19/12/21	Sun	Meeting at Embassy of India	Meeting at Indian Embassy Drone survey at Male'		Meeting at Embassy of India
20/12/21	Mon	Meeting at MNPHI	Meeting at MNPHI Drone survey at Hulhumale		Meeting at MNPHI
21/12/21	Tue	Meeting at MNPHI			
22/12/21	Wed	Meeting at WB, Meeting at MoE, Report to Ministry of Foreign Affairs			
23/12/21	Thu	Meeting at MNPHI, Repor to the Embassy of Japan, Report to JICA Maldives Office			
24/12/21	Fri	Meeting at HDC			
25/12/21	Sat	SQ431, MLE, 12:55, - SIN, 20:45	QR671, MLE, 19:25 - DIA, 22:15	Data collection, report making	SQ431, MLE, 12:55, - SIN, 20:45
26/12/21	Sun	SQ638, SIN, 23:55 - NRT, 07:30	QR806, DIA, 02:00 -NRT, 17:55	Data collection, report making	SQ638, SIN, 23:55 - NRT, 07:30
27/12/21	Mon			Data collection, report making	
28/12/21	Tue			Data collection, report making	
29/12/21	Wed			Field Survey (Male')	
30/12/21	Thu			Field Survey (Hulhumale Island)	
31/12/21	Fri			Data collection, report making	
01/01/22	Sat			Data collection, report making	
02/01/22	Sun			Data collection, report making	
03/01/22	Mon			Data collection, report making	

Appendix11 Officals of concerned agencies

MNPHI	
Shifaz Ali	Minister of State for National Planning, Housing and Infrastructure
Zuhurulla Siyad	Deputy Minister of National Planning, Housing and Infrastructure
Fathimath Shaana Farooq	Director General / Infrastructure Department
Hassan Saamee	Project Coordinator/ Infrastricture Department
Ahmed Aiman Shareef	Coastal Engineer/ Infrastructure Depertment
Miaaza Hussain	Engineer / Infrastructure Department
Mohamed Ghalib	Engineer / Infrastructure Department
HDC	
Suhail ahmed	Managing Director
Mohamed Saif Abdulla	Deputy Director/ Design & Development, Planning and Developmen
Abdulla Firaq	Assistant Director
Fathmath Ushva	Senior Landscape Architect
Hussain Saliq	Civil Engineer
Aminath Samaha	Architect/ Planning and Development
MWSC	
Rusthum Mohamed	General Manager
Mohamed Faisal	Assistant General Manager
Abdul Hameed	Manager
Ibrahim Akram	Assistant Manager/ Business Development
Hussain Hassan	Business Development
Furugaan Ibrahim	Research Development Engineer
Nadha Gasim	Engineer/ Internal Projects
Bushra Hameed	Engineer
Mohamed Nahaas	Assistant officer/ Survey & Design
MLSA	
Mohamed Shafee	Director General
Ahmed Shaniu	Assistant Director
Mohamed Saeed	Geomatic Engineer
MECCT	
Hashim Nabeel	Senior Environment Analyst/ EPA
Ibrahim Humaid	MET Office
Mahid Abdu Rahman	Senior Coastal Analysis/ MECCT
Musab Sabree	Assistant Engineer/ EPA
MMS	
Abdul Muhsim Ramiz	Director
Ahmed Rasheed	Director
Ibrahim Humaid	Seismologis
Nasoon Ismail	Meteorologist
NDMA	

Faroosha Ali	Director of Emergency management
Ibrahim Kashif	Director of Policy & Planning
Mariyam Shizna	Director of Program, Research & Advocacy
Abdulla Rafeeu	Resource Management Officer
Aishath Ifa	Emergency Response Officer
Aminath Izdhiha	Devepoment & Resilience Office
Sonath Abdul Sattar	Project Associate/ WB
MoE	
Fathimath Naseer	Minister of State of Education
Fathimath Azza	Director General
Ibrahim Asif Rasheed	Director General
Aishath Suaadh Abd. Wahhaab	Senior Admin Officer
Aminath Abdul Latheef	Senior Admin Officer
Aishath Zoona	Education Officer
Aminath Najfa	Education Officer
Majidha Ibrahim	Education Officer
Sahula Wajeeh	Education Officer
Yazeedh Mohamed	Administrative Officer
Aminath Yashfa	Consultant Architect (contract)
MNU	
Mohamed Shareef	Vice Chancellor
Aishath Shaheen Ismail	Deputy Vice Chancellor/ Academic Affairs
Aishath Shehenaz Adam	Deputy Vice Chancellor/ Research and Enterprise
WB	
Kwabena Amankwah-Ayeh	Solid Waste Managemen (MUDRP Team leader)
Natsuko Kikutake	Disaster Risk Management (MUDRP Team leader)
Hassan Shiyaz	MNPHI
Shadiya Adam	Maldives Operations Officer